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Report upon the Chicago Water Supply - 1875

REPORT

OF THE

Board of Engineers,

TO THE

CITIZENS' ASSOCIATION,

UPON THE

Chicago Water Supply.

CHICAGO:
HAZLITT & REED, PRINTERS, 172 AND 174 CLARK STREET.
1875.

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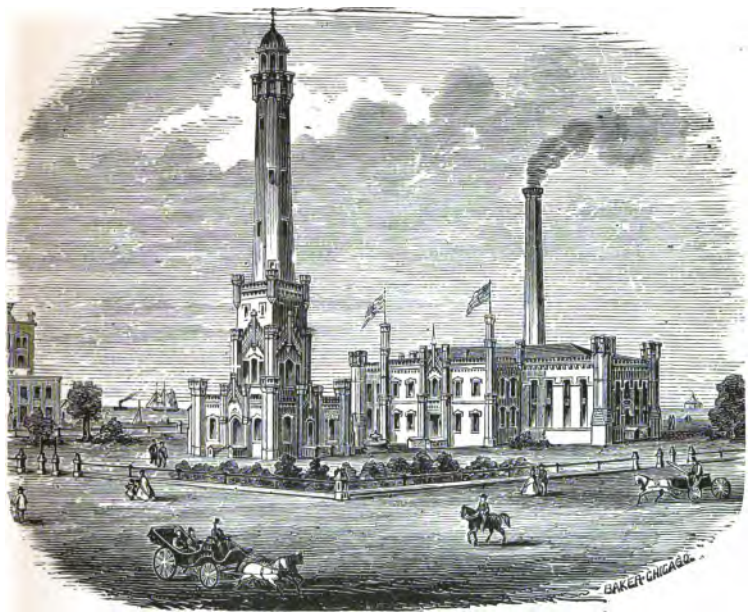
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REPORT.

SEC. 1.

CHICAGO, ILL., Feb. 24, 1875.

FRANKLIN MACVEAGH, ESQ., *President Executive Committee of the Citizens' Association of Chicago:*

DEAR SIR: According to previous agreement, the Committee of Engineers appointed by your Association, met your committee, Mr. E. S. Chesbrough, City Engineer, and Mr. Dewitt C. Cregier, Chief Engineer of the Pumping Works, at noon, November 30, 1874.

After an informal and extended conference, during which the object of appointing the Engineer Committee, the nature and extent of their duties, were frankly and earnestly discussed, it was agreed that it would be best to give this committee specific and limited instructions; the committee then adjourned until four o'clock, P. M.

Upon reassembling, the Executive Committee of the Citizens' Association presented the Engineer Committee with the following preamble and resolutions, as formulating the questions and subjects to be examined and reported upon by said committee.

EXECUTIVE COMMITTEE OF THE
CITIZENS' ASSOCIATION.

SEC. 2.

COPY OF PREAMBLE AND RESOLUTION ADOPTED NOVEMBER 4TH.

WHEREAS, information has been conveyed to this committee in writing and by responsible parties, that the Engines now in use at the Water Works in this city, do not accomplish the work intended and desirable, in supplying the city with water; and that, in addition thereto, the consumption of coal for the said engines is excessive; therefore

Resolved, That a committee of (5) five be appointed by this committee; one of whom shall be a non-resident, and a practical hydraulic engineer, of acknowledged reputation, to investigate the matter and to report to this committee as to the alleged facts; and what, if any, defects or objections exist in the construction or working of said engines.

J. C. AMBLER, *Clerk.*

SEC. 3.

EXECUTIVE COMMITTEE OF THE CITIZENS' ASSOCIATION,
Chicago, Nov. 30, 1874.

MOSES LANE, ESQ., *Chairman:*

DEAR SIR: The preamble and resolution of November 4th, a copy of which is hereby handed to your committee, and the remarks made at the interview with the Executive Committee this afternoon, define the scope of the examination now contemplated, and embrace the following points of inquiry and observation, which are to be confined to the North and South Engines:

1. Whether the engines are up to the capacity claimed for them and defined by contract, plans and specifications.

2. Whether the work is accomplished with a fair degree of economy or otherwise.

3. A comparison between these engines and others in use in large cities is desirable, with a view of obtaining comparative capabilities, and as a consequence of such comparison laying open the defects and objections existing in these engines, if any.

4. Whether these engines, with the addition of those contemplated for the West Division Works, will, in your opinion, be amply sufficient for the needs of the city under all contingencies.

5. As it was observed at the Water Test of October 6th, by reference to private gauges in the South Division, that the pressure which usually stood below 18, was then increased to 36 or over, and as the annual consumption of coal at the works is 15,000 tons, the inquiry arises, assuming that the *average* consumption of coal gives the minimum pressure of 18 or below, what consumption of coal would be required to keep up the pressure to 36 or over? Can the engines be safely worked up to 36 or over all the time? Are they strong enough to bear this continued strain? After considering all these items, is the ultimate result economical?

6. It is deemed desirable to test the pressure at different points, as follows:

Blue Island avenue and Fourteenth street,
State and Twenty-second streets,
La Salle and Washington streets,
Union Park, during the examination.

By order of the Executive Committee.

J. C. AMBLER, *Clerk.*

SEC. 4.

CHICAGO, Dec. 8, 1874.

At a meeting of the Executive Committee, held this day, the following resolution was adopted:

Resolved, That the Committee of Engineers be requested to state what, in their opinion, should be the minimum size of water pipes hereafter to be laid in the water system of this city, in view of its present and prospective needs, and what should be the minimum size of pipe laid from the main to the fire plug.

J. C. AMBLER, *Clerk.*

SEC. 5.

EXECUTIVE COMMITTEE OF THE
CITIZENS' ASSOCIATION OF CHICAGO,
December 17, 1874.

GEN. ALEXANDER SHALER, *Consulting Engineer Fire Department:*

SIR: At the request of the Committee of Engineers recently employed to examine the engines and water system, I beg to propound the following questions:

1. What, in your opinion, will be the maximum number of gallons of water, per minute, required during fire at the following points:

I. The block bounded by Washington, Clark, Madison and LaSalle streets.

II. The block immediately south of I., supposing both blocks were on fire at once.

2. What, in your opinion, will be the maximum number of gallons of water required during fire, at the corner of Madison and LaSalle streets.

An early reply will oblige,

Yours, respectfully,

J. C. AMBLER, *Clerk.*

SEC. 6.

CHICAGO, Dec. 18, 1874.

J. C. AMBLER, ESQ., *Clerk of the Executive Committee of Citizens' Association:*

SIR: In reply to your inquiries this day received, made "at the request of the Committee of Engineers recently employed to examine the Chicago Water System," I have the honor to answer as follows, and in the order presented:

First. "What, in your opinion, will be the maximum number of gallons of water, per minute, required during fire at the following points?"

"1. The block bounded by Washington, Clark, Madison and LaSalle streets."

Should every building in the block be found on fire at the same time, and the avenues of approach open on all sides, every steam engine in the Fire Brigade, numbering twenty-six, would probably be brought into service, and at least fourteen more, making forty in all, might be used to advantage. Forty steam engines could find hydrants within three blocks of the fire. Each engine using a single line of hose would be well supplied with an average of three hundred gallons per minute. As the hydrants are now located, ten of the engines should work two lines of hose, and would be reasonably supplied with four hundred gallons per minute. We may calculate, therefore, in working twenty-six engines, as follows:

16 using 300 gallons per minute.....	4,800
10 " 400 " " "	4,000
	8,800

In working forty engines—

30 using 300 gallons per minute.....	9,000
10 " 400 " " "	4,000
	13,000

"2. The block immediately south of I., supposing both blocks were on fire at once."

Under the same conditions as stated above in the first case, there would be an opportunity of working twenty more engines—that is, sixty in all. Within three blocks of the square referred to, there are hydrants to supply sixty-eight engines.

As there is no probability of such a number ever being brought into service, we may use the calculations made in the first instance for both.

Second. "What, in your opinion, will be the maximum number of gallons of water required, during fire at the corner of Madison and LaSalle streets?"

Understanding that this supposes the case of a single building well on fire, we have only to estimate the quantity likely to be required for supplying six engines, which is about two thousand gallons per minute.

Very respectfully yours,

ALEXANDER SHALER,

Consulting Engineer Fire Department.

SEC. 7. In answer to the foregoing resolutions and questions, the Committee of Engineers submit the following report:

As regards the first point of inquiry, under date of November 30th, the specifications and contract require that the engines shall pump 36,000,000 U. S. gallons of water 150 feet high in twenty-four hours.

The second point of inquiry, under same date, relates to the fuel economy, or "duty," with which the engines accomplish the work.

As the primary or most important requirement of specifications and contract is the quantity of water pumped, and the elevation to which it is to be raised; and as the "duty" or fuel economy, so far as specifications and contract enlighten us, seems to be a matter of

secondary importance; it was concluded to make the capacity and duty trial jointly, and in doing so make a run of fifty consecutive hours.

In order to determine, with a desirable degree of accuracy, whether the engines were capable of meeting the requirements of the specifications and contract, it became necessary to provide means of measuring both the quantity of water pumped and the height to which it was elevated.

To determine the quantity of water pumped, it was at first suggested that all the main supply pipes leading from the pumping works into the city, be isolated from the distributing pipes by closing the stop-gates forming the connections between the two classes of pipes; and to make the sections of main pipes thus isolated, as long as would be admissible in meeting the current demand for water. By this plan, sections of main pipes, varying in length from one to two thousand feet, could have been selected. These sections would have been thus reduced to simple cylindrical conduits, and by placing pressure gauges upon the termini of all the sections of pipe selected, the difference of pressure between the termini of each section could have been ascertained. From these differences of pressures, the heads due the velocities in the respective pipes, and the velocities, it was thought could be calculated. Then with the diameters of the pipes and the velocities, the quantity of water flowing through them, during the engine trial, could be determined.

Upon careful consideration, this plan was not adopted, because it involved too many assumptions; such as getting pressure gauges which correspond exactly, the actual diameters of the pipes being the same as the nominal diameters, the pipes being clean or free from tubercles, the tightness of the connecting gates, and the alignments

of the pipes being as indicated upon the maps. These assumptions constituted too many elements of uncertainty for even approximately accurate results.

SEC. 8. It was then proposed to close the connection between the stand-pipe and the south engines, and pump all the water during the test trial through the thirty-six inch main, discharge it at the river through a branch gate under the pressure due the required head and measure the water by a weir. This plan would have required the thirty-six inch pipe to be cut, a branch and gate put in, the city deprived of the use of its main supply pipe for the length of time required to cut the pipe, put in the branch and gate, and make the test trial; as well as work the engines under abnormal conditions, inasmuch as they would not have had the relief afforded by the stand-pipe.

The proposition was not accepted, principally because it was not deemed wise to deprive the city of its principal supply pipe for any great length of time.

SEC. 9. Third in order, was proposed the use of the formula adopted by Mr. Chesbrough, for calculating the flow of water through the lake tunnel.

Whilst there was neither doubt as regards the degree of accuracy attainable by the use of this formula, nor objection to its use, still it was deemed best to ascertain the quantity of water pumped by means entirely independent of the methods made use of by the officers of the Board of Public Works, inasmuch as their representations as regards the capacity of the engines, have been brought into question. The quantity of water pumped, as determined by the tunnel formula, was used, however, as a check upon the method finally adopted.

SEC. 10. The plan finally adopted, was to construct a weir in the passage leading to the pump-well, by which the quantity of water flowing into the well was gauged. The reason for at all considering the first and second

methods named, was the want of room in the passage to, and in the well, to use a weir. The difference of level necessary between the surfaces of the water in the flume and well, to enable accurate weir gaugings, left so little water in the well, as to make it quite probable that the pumps would, if not very carefully handled, exhaust the well, take air and cause the engines to run off—a contingency which caused the building of a weir to be undertaken very reluctantly.

SEC. 11. In order to have the greatest depth of water in the well practicable, the bulk-head and weir were in the first construction raised to what was estimated the highest admissible level. By the time it was completed, and everything ready for the trial of the engines, the level of the lake, by change of wind, had fallen some nine inches. The consequence was that the weir was too high, and the requisite quantity of water would not flow over it. The trial had to be postponed for thirty hours, the well pumped out and the weir lowered.

SEC. 12. In addition to the weir, graduated gauge-boards, all reading from the plane of reference or City Datum, were placed in the lake and land shafts of the tunnel, and observations made of the water-levels in both shafts during the trial, from which the head under which the flow of water through the tunnel took place was deduced, and from the head, the quantity was determined.

SEC. 13. To determine the head under which the pumps worked during the trial, floats and graduated gauge-boards were placed in the well and stand-pipe, by means of which the water-levels in the two were observed. In the well, the gauge read *minus*, and in the stand-pipe, *plus* plane of reference (City Datum). The sum of any two simultaneous readings constituted the static head under which the pumps worked at the time of observation.

By the head against the pumps is meant the difference of water-levels in well and stand-pipe, which is taken as the height equivalent to which the water was pumped during the trial.

By the head upon the city distribution is meant the difference between City Datum and the height at which the water stood in the stand-pipe.

Pressure gauges, tested and sealed, were attached to boilers, steam-pipe, pump mains, and at four points in the distribution, to fire hydrants.

Indicator cards were taken during the trial from steam, pump, and air-pump cylinders.

SEC. 14. To determine the quantity of coal consumed, tested platform scales were used, and the coal was weighed to the firemen as it was required throughout the whole trial. The weighing and recording the weights was done by clerks employed by your committee, two of whom were on duty at a time. The trial commenced with average steam-pressure and water-levels in the boilers, and perfectly clean fires of maximum value. At the end of fifty hours, the steam-pressure and water-levels in the boilers, as well as the condition of the fires, were brought to precisely the same conditions as they were in the beginning of the trial, so far as the judgment of the committee made this result practicable.

All the coal put into the furnaces during the fifty hours was charged to the engines, and no deduction has been made for ashes, cinders or clinkers.

The feed water to the boilers was measured by a three-inch (3) Worthington meter, located between the hot well and the feed pumps, being on the suction side of the pump. At the conclusion of the trial, the meter was tested by passing (at the average temperature and under the pressure and speed which obtained in feeding the boilers) 185 cubic feet of water and weighing it. It

weighed $\frac{22}{100}$ of one per cent. more than the number of cubic feet indicated by the meter would have weighed at the temperature. That is, the counter of the meter was $\frac{22}{100}$ of one per cent. slow. No correction for this difference has been made in the calculations for reducing the number of pounds of feed water evaporated, per pound of coal, to the standard temperature of 212° Fahr.

SEC. 15. The observations during the trial, and the calculated results, are given in the accompanying Table 1. See appendix.

The table will explain itself by the headings of the columns, with the exception, perhaps, of columns Nos. 14, 15 and 21.

The observations for column 14 were made at intervals of twenty minutes, and for columns 15 and 21, at intervals of ten minutes. In the table they are given in half-hourly averages, in order to make them correspond with the other observations in the divisions of time.

A synopsis of the table is given in the accompanying Table, 2, in which are embraced the principal results only:

SEC. 16. From an inspection of this table, it will be seen that the South Engines, during a run of fifty consecutive hours, pumped 74,316,604 gallons of water, as determined by weir measurement, being at the rate of 35,671,970 gallons per twenty-four hours, or $\frac{91}{100}$ of one per cent. less than the quantity required by specifications and contract. During the same time, the quantity as determined by the tunnel formula, was 76,013,548 gallons, being at the rate of 36,486,503 gallons per twenty-four hours, or $1\frac{35}{100}$ per cent. in excess of the quantity required by specifications and contract. The difference between the weir gauging and tunnel formula being $2\frac{26}{100}$ per cent., the latter mode giving the greater quantity.

As to which of the two methods of determining the quantity of water pumped is the more accurate, is a ques-

tion your committee do not propose to discuss at length; they differ so little, as to indicate that either method approximates a desirable degree of accuracy. It is, therefore, deemed sufficient to say, that whilst the measurement of flowing water by weir is the simplest and most accurate known method, the use of a weir under the conditions it had to be applied in this case, was not wholly satisfactory, but it was believed to be the only applicable mode of determining the quantity of water independent of the tunnel formula.

As to this formula, it had, perhaps, in this instance, the most favorable application, and, so far as this affects the question, it is probably the more accurate under the conditions.

The reason that the engines did not pump the required quantity as determined by weir, was because the water did not flow into the well; they pumped all the water supplied to them, and that, by weir gauging, fell short of the specified quantity nearly one per cent.

After the weir was lowered to the lowest practicable level, the lake continued to recede at this point until it reached a stage of more than one foot below the level at which it was at first supposed the trial of the engines could be made; so that, during the first twenty-five and a half hours of the trial, the specified quantity could not be obtained over the weir. During the last twenty-four and a half hours of the trial, however, a little more than the specified quantity was obtained and pumped. This increase in quantity was brought about, partly by running during two and a half hours (from 11 o'clock P. M., December 11th, to 1.30 A. M., December 12th) while the stand-pipe was full and overflowing, a portion of the water not going into the city, back through the well of the old engines into the branch tunnel behind the weir, and partly by a gradual rise in

the level of the lake; so that during the latter half of the trial the engines pumped, by weir measurement, $\frac{92}{100}$ of one per cent. in excess of the specified quantity. During the two and a half hours in which a portion of the water pumped was returned to the branch tunnel, the engines pumped at the rate of 41,250,979 gallons per twenty-four hours, by weir measurement, and under heads varying from 143.7 to 152.2 feet, or an average of 148.5 feet, from five observations.

Whilst this was causing the engines to perform nearly fifteen per cent. more work than the specified quantity, and was, moreover, going to the extreme limit of prudence with the test, the engines did not disclose any signs of weakness greater than is exhibited by two-thirds of all the large pumping engines in the country when performing their regular daily work. A careful examination of all visible portions of the engines (by two members of your committee) while doing this maximum work, disclosed no defect in strength that gives any reason for apprehending trouble in the future on this point. The examination, however, seemed to disclose the fact that the weakest portion of the machine was in the column support of the beams.

SEC. 17. The head equivalent to which the water was pumped during the trial, was on an average 134.65 feet, falling 15.35 feet short of the specified head.

The fact that the average head equivalent to which the water was pumped, was less than 150 feet, cannot, however, in the opinion of your committee, be construed as a failure on the part of the engines to meet the requirements of the specifications and contract, because the conditions under which they worked made the attainment of 150 feet with a quantity of 36,000,000 gallons, per twenty-four hours, an impossibility.

That is, the consumption of water in the city during

those portions of the trial in which the head was not maintained, was through open service-pipe faucets, sufficiently numerous and capacious to discharge water at the rate of 36,000,000 gallons per twenty-four hours, under a smaller head than 150 feet.

To pump at the rate of 36,000,000 gallons per twenty-four hours, and constantly maintain a head of 150 feet, under the system of "direct supply" which obtains in Chicago, it would be absolutely necessary to have the rate of water consumption uniform, and not greater than the said rate of 36,000,000 gallons per twenty-four hours. The moment the aggregate area of all the open service-faucets in the city is greater than that which will allow the quantity under the specified head to be drawn, the head must become less. On the other hand, the moment the aggregate area of all the open service-faucets is less than that required to discharge the quantity under the specified head, the head must increase; always provided that water is pumped uniformly at the specified rate.

The specified quantity and head together, can, therefore, be maintained only when the rate of consumption in the city is just equal to it.

To guarantee a given head as a condition to be constantly maintained at the pumping station, is to guarantee what cannot be accomplished, unless the pumping capacity is greater than any quantity which can be drawn off under the specified head, by the maximum area of open service-faucets and fire hydrants which may obtain at any one occasion. To maintain such a condition of supply constantly, would require a pumping capacity which no large city in the world possesses.

The engines did pump the required quantity under the specified head, while the rate of consumption in the city

(including waste) made it possible, and, therefore, in the opinion of your committee, complied with the specifications and contract in this respect.

SEC. 18. To answer the second point of inquiry, or determine whether the work has been accomplished with a fair degree of economy, the following Table (A.) has been compiled:

TABLE A.

NO.	TIME OF CONDUCTING TRIALS.	NAMES OF ENGINEERS CONDUCTING TRIALS.	STYLE OF ENGINES.	CITY USING ENGINES.	DURATION OF TRIALS. H. M.	DUTY IN FOOT-POUNDS PER 100 LBS. OF COAL. 1st Method.	2d Method.	3d Method.
1	1856 Dec. 5 & 6	Chas. W. Copeland and W. E. Worthen	Beam, Crank and Fly-wheel.	Hartford, Conn.	8-19	----------	62,661,715	----------
2	1856 Dec. 20	do. do.	Beam, Cornish.	Belleville, N. J.	12-00	----------	72,822,903	73,913,814
3	1857 March 30	Wm. E. Morris and Samuel McElroy	Worthington.	Cambridge, Mass.	9-00	----------	70,463,750	----------
3	1857 June	Fred. Graff and E. W. Smith	do.	do.	14-46	----------	71,278,486	----------
1	1857 July 14	Fred. Graff and W. E. Worthen	B'm, Cr'k & Fly-wheel	Hartford, Conn.	17-47	----------	65,505,469	----------
1	1857 July 15	do. do.	do.	do.	11-52	----------	68,974,549	----------
4	1860 Jan. 12 & 13	E. W. Smith, Fred. Graff and W. E. Worthen	Beam Engine, No. 1.	Brooklyn, N. Y.	26-05	55,019,255	60,798,200	----------
5	1861 Oct. 23 & 24	do. do. do.	do. No. 2.	do.	24-00	----------	58,985,400	----------
5	1862 Feb'y 9 & 10	W. E. Worthen	do. No. 2.	do.	24-00	51,859,533	61,903,700	----------
6	1869 Dec. 23,24 & 25	W. E. Worthen and Chas. W. Copeland	B'm & Fly-wh'l, No. 3	do.	48-00	53,671,579	68,387,200	71,929,600
7	1872 May 15,16 & 17	Jacob Neafie, W. Barnet Le Van, Henry L. Hoff, Geo. H. Bailey and Isaac S. Cassin	Worthington, No. 2.	Belmont, Phila.	48-20	48,219,793	54,416,694	----------
8	1871 Jan. 15 & 16	Chas. Hermany	Hor., Cr'k & Fly-wh'l	Cincinnati, Ohio.	26-20¾	35,573,521	36,172,001	43,566,178
9	1871 Jan. 29 & 30	do.	Vertical, direct do.	do.	19-30	31,990,192	32,969,010	37,789,990
10	1872 Dec. 19 & 20	do.	do. do.	do.	26-00	30,132,372	30,793,052	34,064,977
11	1872 Dec. 11 & 12	do.	Vertical Steam Pump	do.	26-00	21,153,184	21,215,510	23,580,687
12	1871 June 9 & 10	W. E. Worthen, Moses Lane and Geo. W. Fisher	Beam, Cr'k & Fly-wheel, No. 1.	St. Louis, Mo., 1.	28-00	----------	61,307,500	----------
11	1871 June 6 & 7	do. do. do.	do. No. 2.	do. 2.	30-00	----------	61,759,900	----------
14	1874 Dec. 10,11 & 12	Moses Lane, Thos. J. Whitman, Lucian Tilton, Henry Warrington and Chas. Hermany	B'm, Cr'k & Fly-wh'l	Chicago, Ill.	50-00	43,880,476	54,025,762	64,298,251
			South Engines.		13-00	42,072,265	50,485,403	65,824,581
14	1874 Dec. 14 & 15	do. do. do. do.	do.	do.	-----	----------	----------	----------

The engines named in the table are only such as were erected, put in operation, and subjected to formal test-trials, prior to the erection of the engines under investigation.

In Table I. accompanying this report, and in Table B., the duty is given as calculated by three different methods, for the purpose of observing perfect fairness in the comparisons.

By the first method, the engine is credited with the actual quantity of water elevated, the height to which, or equivalent to which, it is elevated, and is charged with the weight of coal consumed.

By the second method, the engine is credited by the load upon the pump-piston, arising from the pressure due the height to which, or equivalent to which, water is elevated, including the pressure from the head due to friction in the pump-main, the pump-piston travel in feet, and is charged with the weight of coal consumed.

By the third method, the engine is credited by the load upon the pump-piston, as measured by the indicator, the piston-travel in feet, and is charged with the weight of coal consumed.

As the duty of the engines named in the table has not been determined by three different methods for all of them, it is given for each, by as many methods as the various reports and accompanying data enable.

The standard duty adopted as representing a fair degree of economy, is taken at 60,000,000 foot pounds per one hundred pounds of coal.

SEC. 19. From an examination of this table, it will be perceived that the Chicago south engines, among fourteen engines named, rank No. 10, as regards the economical use of fuel.

All the engines with which the south engines are com-

pared, were erected and put in operation prior to the erection of the latter, during a period of twenty-five years.

The reason for their ranking lower than might reasonably have been expected (owing to the fact that they were of later design and construction than any which are named) is, in the opinion of your committee, twofold:

First—It has been generally admitted, that the attainment of a high duty was not specially aimed at in the design and construction of these engines; and the impression among engineers acquainted with the Chicago Water Works, so far as your committee are informed on the subject, is, that the principal object had in view in the design of them, was to provide a reliable pumping machine; consequently it is not surprising that the duty attained is not an exceptionally high one. The capacity of the machine, being about double that of any previously constructed, would naturally tend or cause the designer to aim at success rather than economy.

Second—The steam cylinders are unjacketed, and steam is not used with a sufficient degree of expansion, on account of the construction of the boilers being such as not to safely permit steam of sufficiently high pressure to be generated, to obtain a high duty. The engines are balanced by admitting steam during a greater fraction of the up-stroke than during the down-stroke; whilst this is not unfrequently the case in working pumping engines whose steam and pump cylinders are in the same vertical line, and is favorable to steadiness in the structure by storing a greater portion of power in the fly-wheel, while the connections between steam and pump cylinders are under compression, than while in tension, it is not favorable to economy in the use of steam, because it reduces the degree of expansion.

The construction or mechanical workmanship of the engines is good, and, in the opinion of your committee, they fully comply with the specifications and contract.

The second and third points of inquiry are thus jointly answered because they are, in a measure, inseparable.

SEC. 20. The fact is thus established, that during the fifty-hour trial, the south engines performed the work required by the specifications and contract. Whilst this was believed to have been the result at the conclusion of the trial, still the data obtained needed first to be collated and the necessary calculations made before the result could be claimed as positively establishing the fact. And inasmuch as it was known that the result did not vary much from the contract requirements, it was deemed prudent, by your committee, to give the engines a second trial with the weir removed from the passage leading to the well, so as to give the engines all the water they could pump. A second trial, of thirteen hours' duration, was therefore made, and the quantity of water pumped calculated by the tunnel formula. The result of this trial is given in the accompanying Table, 3, from which it will be seen that the total quantity of water pumped was 21,001,489 gallons, or at the rate of 38,771,976 gallons per twenty-four hours—being $7\frac{7}{10}$ per cent. in excess of the contract requirement. This quantity of water, reduced by $2\frac{96}{100}$ per cent.—that is, by the difference between the tunnel formula and weir measurement, as determined during the first trial—will leave the rate of 37,895,729 gallons per twenty-four hours, or $5\frac{27}{100}$ per cent. in excess of the quantity required by the contract.

The height equivalent to which the water was elevated during this second trial, varied from 122.2 to 150.9 feet, or an average from twenty-seven observations of 141.48 feet.

The quantity of water elevated to an equivalent height

of 150 feet, as determined by the tunnel formula, was at the rate of 36,536,394 gallons per twenty-four hours, and reduced to weir measurement, 35,743,251 gallons per twenty-four hours.

During the second trial, therefore, the engines exceeded the contract requirements in every particular, except when the quantity is reduced to weir measurement and a head of 150 feet, they fall short $\frac{71}{100}$ of one per cent., which, however, is not the fault of the engines, as heretofore explained.

SEC. 21. In reply to the fourth point of inquiry, the committee submit the following views:

The engines at the present pumping station, with those in process of construction for the pumping station in the West Division, when all completed and in operation, will not, in the opinion of this committee, "be amply sufficient for the needs of the city under all contingencies." In our opinion, the immediate construction and erection of a third pair of engines, of equal capacity with either the present south engines, or the proposed engines for the West Division, is an absolute necessity, if the water supply of Chicago is to be brought to a state of efficiency and amplitude comparable with the supplies in cities having large reservoirs; always provided, however, that the present rate of water consumption in Chicago is not attended by needless or avoidable waste.

In addition to this recommended increase in the pumping power of these works, your committee are decidedly of the opinion that each pumping engine now in use, and those to be constructed hereafter, should have an independent top instead of bottom connection with its standpipe, for the reason that if thus connected, any number of engines can pump into the distribution without the slightest interference, one with the other, so long as the quantity pumped is not greater than the capacity of the

distribution and services: and for the further and more important reason, that such an arrangement will enable the adding to the currently running machines, one engine after another, without the slightest danger of accident, until every reserve machine in the department is in operation, should an emergency arise, such as a great fire, that would make such a union of all the pumping power necessary. In the opinion of your committee, a combination like this is not practicable with single stand-pipes or bottom connections, except at constant hazard and frequent accidents, as well as interruptions to the water supply.

This increase of pumping power is also believed to be necessary to meet the annually recurring demands during the hot weather. It has been found, by observation, in cities supplied by reservoirs, that the maximum hourly consumption in summer, during prolonged periods of hot weather, is, for hours in succession, at a rate three times that of the average during the year for all purposes. In order, therefore, to make a water works upon the system of *direct supply* as efficient and ample as a works upon the system of *indirect supply* with large reservoirs, it is necessary to have pumping machinery of sufficient capacity to supply, for the ordinary uses in summer, at three times the rate of the average consumption for the year; and, in addition to this, sufficient machinery to supply extraordinary demands caused by fires, as well as a proper addition for inoperative machines undergoing repairs. Or, in other words, a system of *direct supply* is equally efficient and ample as an *indirect supply* with large reservoir, when it has pumping machinery capable of delivering on demand, as promptly, with as much safety, and as great a quantity, as can be delivered by the reservoir.

Whilst these are facts which are, perhaps, popularly known, their abstract consideration does not so fully illustrate the comparative merits of the *direct* and *indirect*

systems of supply, as a comparison between the water supplies of Brooklyn, Saint Louis, and Chicago—cities of approximately the same population. By an examination of the Brooklyn water supply, it will be found that when two-thirds of the pumping capacity of the engines are in action, the city can be furnished continuously at the rate of 32,000,000 gallons per twenty-four hours. But during the hours of greatest demand, by the aid of the reservoir, the water will flow to the city at the rate of 2,500,000 gallons per hour, with a loss of head of about sixty feet. This latter quantity of water is at the rate of 2.42 times the average hourly consumption for the year 1874.

At Saint Louis, with two-thirds of the pumping capacity of the engines in action, the city can be furnished, continuously, at the rate of 37,333,333 gallons each twenty-four hours. But during the hours of greatest demand, by aid of the reservoir, the water will flow to the city at the rate of 2,750,000 gallons per hour, with a loss of head of about fifty feet. This latter quantity of water is at the rate of 3.67 times the average hourly consumption for the year 1874.

Chicago, having two-thirds of the pumping capacity of the engines in action, can be continuously supplied at the rate of 2,083,333 gallons per hour, under a loss of head of about forty feet. This latter quantity of water is at the rate of 1.41 times the average hourly supply during 1874 (assuming that to have been at the rate of 36,000,000 gallons per twenty-four hours). As Chicago has no reservoir, this is the full measure of supply under the conditions of safety named, therefore the greatest hourly demand cannot be responded to.

In this comparison, Chicago is clearly shown to possess much the smallest margin of safety in her water supply during the hours of greatest demand.

Now assume, that by the time the engines under con-

tract, and those recommended by this committee, are completed and brought into service, the average daily consumption of water has reached 40,000,000 gallons per twenty-four hours, and the contemplated and needed main pipes have been added, the comparison will stand thus: With one-third of the pumping capacity in reserve, the city can be supplied at the rate of 4,083,333 gallons of water per hour, with a loss of head of about forty feet. This latter quantity of water is at the rate of 2.48 times the estimated average hourly consumption at the completion of the recommended engines. This would bring the Chicago water supply about on an equality with what now obtains in Brooklyn and Saint Louis.

It thus appears, that what at first sight might be considered as more than an ample pumping capacity, does still not place the Chicago water supply ahead of the water supplies of Brooklyn and Saint Louis.

SEC. 22. The fifth point of inquiry, your committee are not able to answer definitely, because they are not informed as to what quantity of water was pumped during the interval of time in which the maximum pressure of thirty-six pounds per square inch was obtained in the "water test" alluded to.

On the accompanying chart are graphic representations of the quantity of water pumped, as measured by tunnel, weir and pump; the pressures due the varying heights of water in the stand-pipe; and the pressures as read from four different pressure gauges attached to four fire hydrants at different points in the city, all reduced to the plane of reference or City Datum.

The quantities and pressures thus represented, did obtain during the trial, and may be taken as representing about ninety-five (95) per cent. of the maximum capacity of these engines.

While the rate of water consumption in the city is less than 1,500,000 gallons per hour under a head of one hundred and fifty feet, the engines are capable of regulating the pressure, but as soon as the consumption exceeds this quantity under a head of one hundred and fifty feet, the head diminishes and the engines (although pumping at the rate of 1,500,000 gallons per hour) cease to control the head or pressure, because the rate of consumption exceeds the capacity of the engines under the named head, and the pressure is regulated by the water consumers with the open service faucets, which regulation of pressure is continued by them just as long as their wants are greater than at the rate of 1,500,000 gallons per hour under the specified head.

It is true, however, that under a diminished head, the engines might, with safety, be run up to say at a rate of 40,000,000 gallons per twenty-four hours, but they cannot be guaranteed to maintain a greater pressure than the open service faucets make practicable, so long as the aggregate capacity of the latter to draw water is greater than the capacity of the engines. Neither is the pressure which may obtain in any given locality susceptible of determination by calculation, because it depends upon unknown causes, chief among which is the quantity of water which may be needed at any time or locality.

The quantity of coal with which the engines performed the work represented upon the chart, was at an average rate of 3,855 lbs. per hour, or 16,896.465 tons per annum.

SEC. 23. In reply to your resolution of December 8th, as to "what should be the minimum size of pipes to be hereafter laid in the water distribution of Chicago," your committee submit the following:

In the experience with water supplies for all cities with which your committee are acquainted, it has been found that the sizes of pipe which at one time furnished an

ample supply for all purposes, were found inadequate to the demands in the future, at intervals of time varying in duration with the conditions under which the different distributions were planned and constructed, and had to be enlarged as necessity required and means enabled—which was, perhaps, in most cases, accomplished economically. From this experience and our own judgment, we conclude that, consistently with true economy, the minimum size of pipes which should be laid in any particular city, cannot be predetermined for any great length of time, principally for the reason that the ratio of increase in the consumption of water simply follows the law of demand, a correct knowledge of which cannot be had for any great length of time in advance, consequently the distributing pipes in most cities must be subject to periodical adjustments by additions and substitutions of larger pipe.

In the cities of Brooklyn and Saint Louis, the minimum sizes of distributing pipes were fixed in each case at six inches in diameter—in the former city eighteen years, and in the latter eight years ago. If this question in those cities were to be decided at the present time, with the experience they have had, the minimum sizes for some portions of those cities would probably be greater than six inches.

In view of the foregoing, your committee are of the opinion that in Chicago the minimum size of pipe hereafter to be laid, in order to prudently provide for the future increase in the demand for water, may be six inches for the outlying or less densely built up districts, and in the heart of the city, where the most costly structures are covering the whole available building area, and where the valuable products of industry are concentrated and stored, no pipes less than eight inches in diameter should be laid. And in some localities, where it will, per-

haps, be found advisable to take up one or several lines of small pipes, there should be substituted pipes of ten and in some cases twelve inches in diameter, governed, of course, by experience and judgment.

SEC. 24. We have thus, at length and in detail, answered the resolutions and questions submitted to us by your committee, and we conclude our report by a recapitulation of the whole subject.

Question 1.—"Whether the engines are up to the capacity claimed for them and defined by contract, plans and specifications?"

Answer—The engines are, in our opinion, fully up to the capacity demanded by contract, plans and specifications.

Question 2—"Whether the work is accomplished with a fair degree of economy or otherwise?"

Answer—The work is not accomplished with a fair degree of economy.

Question 3—"A comparison between these engines and others in large cities is desirable, with a view of obtaining comparative capabilities, and as a consequence of such comparison, laying open the defects and objections existing in the engines, if any."

Answer—In the opinion of this committee, with the exception of the question of economy, answered in reply to question No. 2, these engines compare favorably with the large pumping engines used in other cities in this country.

Question 4—"Whether these engines, with the addition of those contemplated for the West Division Works, will, in your opinion, be amply sufficient for the needs of the city under all contingencies?"

Answer—They will not. It is our opinion that additional engines of not less capacity than the engines now being constructed, should immediately be contracted for, in order to bring the water supply of Chicago on an equality—as regards safety, satisfactory head, and reliability—with other large cities.

Question 5—"As it was observed at the water test of October 6th, by reference to private gauges in the South Division, that the pressure which usually stood below 18 was then increased to 36, or over, and as the annual consumption of coal at the works is fifteen thousand tons, the question arises: Assuming that the *average* consumption of coal gives the minimum pressure of 18 lbs. or below, what consumption of coal would be required to keep up the pressure to 36 or over?"

(*a*) "Can these engines be safely worked to 36 or over all the time? Are they strong enough to bear this continued tension?"

(*b*) "After considering all these items, is the ultimate result economical?"

Answer—The pressures which obtained during the trial, at four points in the city, are shown upon the accompanying chart. The quantity of coal used during the time these pressures obtained, was at the rate of 3,855 lbs. per hour—equal to a yearly consumption of 16,896.465 tons. As shown on the chart, the difference of pressure, as indicated at different times on the same gauge, would show a change of the height of water in the stand-pipe, rather than the quantity of coal consumed. The pressure in the city and the quantity of coal consumed at the pumping station, do not bear any direct relation to each other, consequently no answer can be given to the first section of this question.

(*a*) The engines can safely maintain the pressures which

obtained during the trial, which are represented upon the chart; or, in other words, they can safely maintain any pressure which a rate of 36,000,000 gallons per twenty-four hours, under a head of 150 feet, makes practicable.

(*b*) This portion of question No. 5 is answered by answer to question No. 2.

No. 6. The pressures at four fire-hydrants, viz.: at LaSalle and Washington streets; Union Park; State and Twenty-second streets; and Blue Island avenue and Fourteenth street, were taken every ten minutes during the entire trial of fifty hours, and the results are shown upon the accompanying chart.

Question of December 8, 1874—"What, in your opinion, should be the minimum size of water pipes hereafter to be laid in the water system of Chicago?" and (*a*) "what should be the minimum size of pipe laid from the main to the fire-hydrants?"

Answer—In our opinion, no pipes less than six inches should be laid in any part of the city, and that in certain districts, the minimum size laid should be eight inches, or larger.

(*a*) The minimum size from the mains to the fire-hydrants should be not less than six inches.

At the suggestion of this committee, you have requested Gen. Alexander Shaler, Consulting Engineer of the Chicago Fire Department, to state what would probably be the maximum quantity of water required in case of fire in two specified localities.

Gen. Shaler's estimate has been duly considered, and the pipes, for the district in which it is proposed to obtain the water, as represented upon the maps, carefully examined.

If the pipes laid in the named district are of the sizes represented, and the connections between the fire-hy-

drants and these pipes six inches in diameter, your committee are of the opinion that the estimated quantity of water can be easily obtained in the district named, provided the height of water in the stand-pipe be maintained at or above one hundred and forty feet.

Respectfully submitted.

CHAS. HERMANY,
THOS. J. WHITMAN,
MOSES LANE,
H. WARRINGTON,
L. TILTON.

TABLE I.

SOUTH ENGINES—FIRST TRIAL.

DATE.	TIME.	PRESSURES.					TEMPERATURES—Deg. Fah.					
December.		Atmospheric Barometer.	Vacuum Gauge.	Steam in Boilers	Steam in Steam pipe	Water Gauge at Engine	Open Air	Engine Room.	Boiler Room.	Water in Pump Well.	Boiler feed Water.	Steam near Throttle Valve.
18-4.	H. M.	In.	In.	Lbs.	Lbs.	Lbs.						
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
16th.	1.00 P. M.	29.32	26.5	35	30	42	25	68	70	32	105	——
	1.30	29.32	26.5	33	28	40	25	68	64	32	105	——
	2.00	29.32	26.5	32	30	50	25	68	65	32	98	——
	2.30	29.32	26.5	33	28	50	25	68	70	32	112	——
	10.00	29.32	26.5	32	28	52	25	68	65	32	114	——
	10.30	29.32	26.5	32	29	52	25	70	70	32	116	——
	11.00	29.32	26.5	32	29	52	22	70	71	32	117	——
Totals	3 Hours.											
Averages..		29.32	26.5	30.5	28.5	50	22.3	70.2	70.3	32	110.5	
17th.	11.30	29.32	26.5	28	30	54	22	70	71	32	109	——
	12.00	29.32	26.5	32	28	52	22	70	70	32	113	——
	12.30	29.32	26.5	32	28	52	22	68	70	32	114	——
	1.00	29.32	26.5	32	28	54	23	70	70	32	114	——
	1.30	29.25	26.5	32	27	50	24	71	70	32	114	——
	2.00	29.25	26.5	32	28	53	25	71	70	32	115	——
	2.30	29.24	26.5	33	29	55	26	71	71	32	118	——
	3.00	29.24	26.5	33	29	55	27	71	70	32	108	——
	3.30	29.24	26.5	33	29	53	27	72	71	32	115	——
	4.00	29.24	26.5	33	29	53	27	72	70	32	107	——
	4.30	29.22	26.5	33	29	52	27	72	75	32	111	——
	5.00	29.22	26.5	33	29	53	27	73	77	32	109	——
	5.30	29.22	26.5	33	29	53	27	72	77	32	110	——
	6.00	29.22	26.5	33	30	54	27	73	74	32	113	——
	6.30	29.22	26.5	33	30	53	26	73	72	32	114	——
Totals	7½ Hours.											
Averages..		29.22	26.5	32	29	53	25.2	71.4	73.4	32	111.9	
	7.00	29.24	25.0	33	30	44	26	73	74	32	115	——
	7.30	29.24	26.5	33	29	42	27	72	74	32	114	——
	8.00	29.24	26.5	32	28	40	27	68	74	31	113	——
	8.30	29.25	26.5	32	28.5	40	28	72	74	31	114	——
	9.00	29.25	26.5	32	28.5	40	28	72	76	32	110	——
	9.30	29.25	28.0	32	29	38	29	72	78	32	116	——
	10.00	29.26	27.0	32	28	39	28	64	67	31.5	109	——
	10.30	29.27	27.0	31	27	36	28	64	68	31.5	117	——
	11.00	29.27	27.0	31	29	40	27	68	77	32	112	——
	11.30	29.28	26.0	31	29	39	26	71	77	31	111	——
	12.00 M.	29.28	26.5	32	28.5	41	26	70	77	32	115	——
	12.30	29.27	26.0	31.5	28	42	26	70	77	31.5	114	——
	1.00	29.26	26.5	31.5	27	42	25	70	79	31	120	——
	1.30	29.26	26.5	31.5	29	41	26	70	70	32	113	——
	2.00	29.26	26.5	32	27.5	41	26	70	86	31.5	113	——
	2.30	29.25	26.5	32	28	41	26	70	74	32	118	——
	3.00	29.26	27.0	31.5	29	42	24	69	80	31.5	117	——
	3.30	29.27	26.5	32.5	29	43	24.5	70	79	32	116	——
	4.00	29.27	27.0	32	29	42	23	70	78	32	114	——
	4.30	29.00	26.5	32	29	44	22	70	80	32	114	——
	5.00	29.00	26.5	33	28	41	22	70	85	32	110	270
	5.30	29.01	26.5	32	29	44	22	70	79	32	112	——
	6.00	29.01	27.0	31	28	43	21	70	84	32	110	——
	6.30	29.03	26.5	32	28	45	20	70	83	32	115	——
	7.00	29.03	26.5	32	29	45	19	69	82	32	109	——
	7.30	29.03	27.0	32	28	47	19	69	83	32	111	——
	8.00	29.03	27.0	33	30	44	18	70	81	32	104	——
	8.30	29.03	26.5	32	28	49	18	70	84	32	114	——
	9.00	29.02	27.0	33	29	49	18	70	82	32	114	273
	9.30	29.02	26.5	33	30	51	16	70	82	32	113	——
Totals	15 Hours.											
Averages..		29.28	26.6	32	28.5	42.6	24.	69.2	79.4	32.	113.	——

TABLE 1.—Continued.

SOUTH ENGINES — FIRST TRIAL.

DATE.	TIME.	PRESSURES.					TEMPERATURES — DEG. FAH.					
DECEMB'R		Aneroid Barometer.	Vacuum Gauge.	Steam in Boiler.	Steam in Steam-pipe.	Water Gauge at Engine.	Open Air.	Engine Room.	Boiler Room.	Water in Pump-well.	Boiler Feed Water.	Steam near Throttle Valve.
1874.	H. M.	In.	In.	Lbs.	Lbs.	Lbs.						
1	2	3	4	5	6	7	8	9	10	11	12	13
11th.	10.00	29.92	26.5	33	30	53	16	70	81	32	113	273
	10.30	29.92	26.5	32	30	54	15	69	81	32	116	----
	11.00	29.92	26.5	33	29	54	15	69	80	32	118	272
	11.30	29.93	26.5	34	30	54	14	68	76	32	121	----
12th.	12.00	29.93	26.5	33	30	54	15	69	81	32	111	273
	12.30	29.91	26.5	29	30	53	14	69	81	32	109	----
	1.00	29.91	26.5	29	29	54	14	68	82	32	110	272
	1.30	29.91	26.5	29	29.5	52	12	68	83	32	112	----
	2.00	29.90	26.5	29	29	51	14	68	82	31.5	114	273
	2.30	29.91	26.5	29	29	51	12	68	81	31	112	----
	3.00	29.90	26.5	29	29	54	13	68	82	31	113	270
	3.30	29.90	26.5	28	29	54	13	67	79	31	115	----
	4.00	29.90	26.5	29	29	54	13	68	80	31.5	118	----
	4.30	29.90	26.5	29	28.5	55	13	67	80	31.5	118	260
	5.00	29.90	26.0	29	29	54	12	68	80	32	119	----
	5.30	29.90	27.0	29	29.5	51	12	68	81	32	117	----
	6.00	29.90	26.0	29	30	53	12	67	82	32	122	250
TOTALS..	8½ Hrs.											
AVERAGES		29.91	26.4	30	29	53	13.5	68	80	31.7	115.2	----
	6.30	29.90	27.0	29	29	50	14	68	78	32	115	266
	7.00	29.90	26.0	30	30	47	14	67	81	32	112	----
	7.30	29.90	26.0	29	29.5	45	14	68	79	32	120	----
	8.00	29.90	26.5	29	29	44	15	68	78	32	118	----
	8.30	29.90	26.5	29	30	41	18	68	80	32	116	----
	9.00	29.90	26.5	29	30	38	22	67	80	32	110	273
	9.30	29.90	26.5	29	30	37	22	73	84	32	116	----
	10.00	29.90	26.5	30	30	38	22	69	85	32	116	266
	10.30	29.90	26.5	29	30	38	22	69	84	32	115	----
	11.00	29.87	26.5	29	29	38	24	69	83	32	114	272
	11.30	29.87	26.5	29	29	37	27	69	88	32	111	----
	12 M.	29.84	26.5	29	29	39	28	70	91	32	112	270
	12.30	29.83	26.5	29	29	39	28	70	89	32	112	----
	1.00	29.82	26.5	29	29	39	30	70	88	32	114	270
	1.30	29.81	26.5	29	29	39	31	71	91	32	114	----
	2.00	29.78	26.5	29	29	40	32	71	85	32	115	270
	2.30	29.77	26.5	29	29	40	32	71	84	32	112	----
	3.00	29.76	26.5	29	29	39	31	71	87	32	112	270
	3.30	29.75	26.5	29	29	40	30	71	92	32	112	----
	4.00	29.74	26.0	29	30	43	30	70	91	32	113	----
	4.30	29.74	26.5	29	29	40	30	70	90	32	112	----
	5.00	29.74	27.0	30	30	40	31	71	86	32	112	265
	5.30	29.74	26.5	30	28	44	30	70	86	32	112	----
	6.00	29.74	26.0	29	30	44	31.5	72	87	32	112	----
	6.30	29.74	26.5	28	28	47	31	72	90	32	113	260
	7.00	29.74	26.5	29	30	47	31	72	87	32	110	----
	7.30	29.74	27.0	31	30	47	32	72	88	32	110	----
	8.00	29.69	26.5	30	30	49	32	72	88	31	112	----
	8.30	29.69	27.0	31	30	48	31	70	87	31	110	----
	9.00	29.65	26.5	30	29.5	50	31	72	84	32	112	250
	9.30	29.65	26.5	30	31	50	32	72	84	31	111	----
	10.00	29.65	26.5	28	30	53	32	72	84	32	111	250
TOTALS..	16 Hrs.											
AVERAGES		29.79	26.5	29.2	29.4	42.8	26.9	70	85.6	31.9	113	----
	50 Hrs.	29.84	26.52	30.68	28.95	46.43	23.25	69.58	79.83	31.92	113.06	

TABLE 1.—Continued.

SOUTH ENGINES—FIRST TRIAL.

DATE.	TIME.	WATER LEVELS + P. R.						
DECEMBER.		Lake Shaft, 1st Tunnel.	Land Shaft, 1st Tunnel.	Fall between Lake and Land Shaft.	Height of Water in Flume.	Fall between Land Shaft and Flume.	Crest of Weir.	Height of Hook Gauge, Zero.
1874.	H. M.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1	2	14	15	16	17	18	19	20
10th.	8 P. M.	+	—				—	
	8.30	0.593	3.576	4.169			6.680	4.000
	9.00	0.595	4.006	4.601				
	9.30	0.652	3.930	4.588	4.686	0.750		
	10.00	0.663	4.030	4.693	4.824	0.794		
	10.30	0.687	3.973	4.660	4.774	0.801		
	11.00	0.570	3.933	4.503	4.770	0.837		
TOTALS	3 Hours.							
AVERAGES		0.62983	3.909	4.53883	4.7635	0.7955	6.680	4.000
	11.30	0.477	4.066	4.543	4.810	0.744	6.680	4.000
11th.	12.00	0.510	4.016	4.526	4.749	0.733		
	12.30	0.410	4.036	4.446	4.765	0.729		
	1.00	0.275	4.060	4.335	4.768	0.708		
	1.30	0.345	4.076	4.421	4.808	0.732		
	2.00	0.410	3.970	4.380	4.661	0.791		
	2.30	0.478	3.833	4.311	4.527	0.694		
	3.00	0.530	3.843	4.373	4.607	0.767		
	3.30	0.653	3.080	3.733				
	4.00	0.670	3.100	3.770				
	4.30	0.838	2.886	3.724				
	5.00	0.914	2.923	3.837				
	5.30	0.870	3.053	3.923				
	6.00	0.945	3.316	4.261				
	6.30	0.940	3.513	4.453	4.432	0.919		
TOTALS	7½ Hrs.							
AVERAGES		0.6216	3.58473	4.20633			6.680	4.000
	7.00	0.880	3.900	4.780	4.671	0.771	6.680	4.000
	7.30	0.820	3.906	4.726	4.675	0.769		
	8.00	0.698	3.976	4.674	4.684	0.708		
	8.30	0.818	3.963	4.781	4.736	0.773		
	9.00	0.805	4.026	4.831	4.838	0.812		
	9.30	0.825	4.013	4.838	4.823	0.810		
	10.00	0.690	3.940	4.630	4.689	0.749		
	10.30	0.676	4.010	4.686	4.790	0.780		
	11.00	0.713	4.033	4.746	4.782	0.749		
	11.30	0.711	4.066	4.777	4.797	0.731		
	12 M.	0.640	4.066	4.706	4.757	0.691		
	12.30	0.666	3.983	4.649	4.728	0.745		
	1.00	0.875	4.016	4.891	4.828	0.812		
	1.30	0.840	3.996	4.836	4.697	0.701		
	2.00	0.730	3.940	4.670	4.687	0.747		
	2.30	0.766	4.053	4.819	4.841	0.788		
	3.00	0.840	4.056	4.896	4.844	0.788		
	3.30	0.866	3.926	4.792	4.724	0.798		
	4.00	0.780	3.980	4.760	4.741	0.761		
	4.30	0.806	4.050	4.856	4.837	0.787		
	5.00	0.685	4.016	4.701	4.704	0.688		
	5.30	0.673	4.066	4.739	4.823	0.757		
	6.00	0.615	4.016	4.631	4.738	0.722		
	6.30	0.581	3.953	4.534	4.685	0.732		
	7.00	0.565	4.100	4.665	4.787	0.687		
	7.30	0.728	4.026	4.754	4.840	0.814		
	8.00	0.770	3.920	4.690	4.686	0.766		
	8.30	0.718	4.020	4.738	4.801	0.781		
	9.00	0.670	3.963	4.633	4.741	0.778		
	9.30	0.716	4.050	4.766	4.827	0.777		
TOTALS	15 Hours.							
AVERAGES		0.73863	4.00097	4.7396	4.76004	0.7524	6.680	4.000

TABLE 1.—Continued.

SOUTH ENGINES—FIRST TRIAL.

DATE.	TIME.	WATER LEVELS + P. R.						
DECEMBER.		Lake Shaft, 1st Tunnel.	Land Shaft, 1st Tunnel.	Fall between Lake and Land Shaft.	Height of Water in Flume.	Fall between Land Shaft and Flume.	Crest of Weir.	Height of Hook Gauge, Zero.
1874.	H. M.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1.	2.	14.	15.	16.	17.	18.	19.	20.
	P. M.	+	—				—	
11th.	10.00	0.745	4.026	4.771	4.827	0.801	6.680	4.000
	10.30	0.746	4.003	4.749	4.773	0.770	----	----
	11.00	0.785	3.993	4.778	4.730	0.737	----	----
	11.30	0.826	3.836	4.662	4.595	0.759	----	----
12th.	12.00	0.870	3.906	4.776	4.660	0.754	----	----
	12.30	0.923	3.740	4.663	4.516	0.776	----	----
	1.00	0.835	3.683	4.518	4.445	0.838	----	----
	1.30	0.808	3.653	4.461	4.460	0.807	----	----
	2.00	0.800	3.630	4.430	4.803	1.173	----	----
	2.30	0.738	3.673	4.411	4.854	1.181	----	----
	3.00	0.745	3.883	4.628	4.717	0.834	----	----
	3.30	0.626	3.783	4.406	4.776	0.993	----	----
	4.00	0.625	3.900	4.525	4.766	0.866	----	----
	4.30	0.675	3.936	4.611	4.693	0.757	----	----
	5.00	0.670	3.943	4.613	4.688	0.745	----	----
	5.30	0.725	3.930	4.655	4.685	0.755	----	----
	6.00	0.780	4.006	4.786	4.785	0.779	----	----
TOTALS	8½ Hrs.							
AVERAGES.....		0.7601	3.8543	4.6144	4.6925	0.84385	6.680	4.000
	6.30	0.825	4.043	4.868	4.775	0.732	6.680	4.000
	7.00	0.855	3.960	4.815	4.680	0.720	----	----
	7.30	0.913	3.986	4.899	4.784	0.798	----	----
	8.00	0.805	3.950	4.755	4.681	0.731	----	----
	8.30	0.808	3.920	4.728	4.672	0.752	----	----
	9.00	0.630	3.963	4.593	4.689	0.726	----	----
	9.30	0.663	3.946	4.609	4.683	0.737	----	----
	10.00	0.770	3.936	4.706	4.678	0.742	----	----
	10.30	0.771	3.943	4.714	4.675	0.732	----	----
	11.00	0.690	3.966	4.656	4.690	0.724	----	----
	11.30	0.676	3.966	4.642	4.689	0.723	----	----
	12.00 M.	0.670	3.930	4.600	4.684	0.754	----	----
	12.30	0.641	3.953	4.594	4.687	0.734	----	----
	1.00	0.815	3.953	4.768	4.758	0.805	----	----
	1.30	0.726	4.073	4.799	4.851	0.788	----	----
	2.00	0.755	4.060	4.815	4.780	0.720	----	----
	2.30	0.818	3.950	4.768	4.789	0.779	----	----
	3.00	0.780	3.910	4.690	4.670	0.760	----	----
	3.30	0.776	3.910	4.686	4.683	0.773	----	----
	4.00	0.970	4.006	4.976	4.765	0.759	----	----
	4.30	0.920	3.900	4.820	4.656	0.756	----	----
	5.00	0.955	3.900	4.855	4.667	0.767	----	----
	5.30	0.958	3.933	4.891	4.731	0.798	----	----
	6.00	0.962	3.936	4.898	4.666	0.730	----	----
	6.30	0.965	3.973	4.938	4.777	0.804	----	----
	7.00	0.969	3.943	4.912	4.717	0.774	----	----
	7.30	0.972	3.913	4.885	4.691	0.778	----	----
	8.00	0.976	3.986	4.962	4.795	0.809	----	----
	8.30	0.980	3.926	4.906	4.686	0.760	----	----
	9.00	0.983	4.013	4.996	4.802	0.789	----	----
	9.30	0.987	3.986	4.973	4.684	0.698	----	----
	10.00	0.991	3.946	4.937	4.677	0.731	----	----
TOTALS	16 Hours.							
AVERAGES.....		0.84299	3.9587	4.80169	4.7141	0.75572	6.680	4.000
	50 Hours.	0.751593	3.894555	4.646148			6.680	4.000

TABLE 1.—Continued.

SOUTH ENGINES — FIRST TRIAL.

DATE.	TIME.	WATER LEVELS + P. R.					PRESSURES.	
DECEMBER.		Reading of Hook Gauge.	Depth of Water on Weir.	In Pump-well.	In Stand-pipe.	Head against Pumps.	Gauge on South Pump Main.	Gauge on North Pump Main.
1874.	H. M.	Feet.	Feet.	Feet.	Feet.	Feet.	Lbs.	Lbs.
1	2	21	22	23	24	25	26	27
10th.	8 P.M.	.....	.....	—4.3	+118.5	122.8	40	42
	8.30	.....	.....	6.5	128.5	135.0	47	45
	9.00	.....	.....	6.9	132.0	138.9	47	46
	9.30	2.006	1.994	7.1	134.7	141.8	50	49
	10.00	2.144	1.856	7.3	136.8	144.1	51	50
	10.30	2.094	1.906	6.9	137.8	144.7	51	50
	11.00	2.090	1.910	7.2	140.6	147.8	52	51
TOTALS	3 Hrs.							
AVERAGES....		2.0855	1.9145	7.0	135.0	142.0	49.6	48.5
	11.30	2.130	1.870	—10.0	+141.6	151.6	54	53
11th.	12.00	2.069	1.931	6.5	139.7	146.2	51	51
	12.30	2.085	1.915	7.0	140.0	147.0	52	51
	1.00	2.088	1.912	6.9	141.9	148.8	53	52
	1.30	2.128	1.872	6.2	139.0	145.2	53	52
	2.00	1.981	2.019	6.2	139.5	145.7	53	51
	2.30	1.847	2.153	5.6	145.4	151.0	55	54
	3.00	1.927	2.073	4.8	145.4	150.2	55	55
	3.30	.....	.....	4.0	145.4	149.4	54	54
	4.00	.....	.....	4.0	141.9	145.9	54	53
	4.30	.....	.....	3.7	145.4	149.1	53	53
	5.00	.....	.....	3.8	142.5	146.3	53	54
	5.30	.....	.....	4.1	145.4	149.5	52	53
	6.00	.....	.....	4.5	140.5	145.0	53	54
	6.30	1.752	2.248	5.3	142.0	147.3	53	53
TOTALS	7½ Hrs.							
AVERAGES...		.....	.....	5.51	142.4	147.91	53.2	52.9
	7.00	1.991	2.009	—7.7	+116.5	124.2	48	48
	7.30	1.995	2.005	8.5	117.7	126.2	44	44
	8.00	2.004	1.996	9.0	111.7	120.7	40	43
	8.30	2.056	1.944	7.5	112.7	120.2	41	43
	9.00	2.158	1.842	7.5	111.5	119.0	40	41
	9.30	2.143	1.857	7.5	114.7	122.2	40	43
	10.00	2.009	1.991	8.0	110.5	118.5	39	40
	10.30	2.110	1.890	7.0	119.5	116.5	38	43
	11.00	2.102	1.898	7.3	111.4	118.7	40	42
	11.30	2.117	1.883	8.7	108.4	117.1	38	40
	12. M	2.077	1.923	7.6	113.2	120.8	40	43
	12.30	2.048	1.952	8.0	117.5	125.5	41	44
	1.00	2.148	1.852	7.9	115.8	123.7	42	45
	1.30	2.017	1.983	9.2	113.6	122.8	42	44
	2.00	2.007	1.993	7.5	117.3	124.8	40	43
	2.30	2.161	1.839	7.8	118.2	126.0	43	44
	3.00	2.164	1.836	8.7	115.0	123.7	43	44
	3.30	2.044	1.956	7.3	121.2	128.5	44	45
	4.00	2.061	1.939	8.3	117.0	125.3	43	45
	4.30	2.157	1.843	7.7	119.8	127.5	43	44
	5.00	2.024	1.976	7.6	115.0	122.6	41	42
	5.30	2.143	1.857	8.1	115.0	123.1	43	44
	6.00	2.058	1.942	6.2	122.3	128.5	43	44
	6.30	2.005	1.995	6.5	128.0	134.5	45	45
	7.00	2.107	1.893	7.3	125.3	132.6	44	45
	7.30	2.160	1.840	7.4	130.0	137.4	47	47
	8.00	2.006	1.994	8.1	132.6	140.7	45	45
	8.30	2.121	1.879	7.1	135.4	142.5	48	49
	9.00	2.061	1.939	8.4	132.5	140.9	48	49
	9.30	2.147	1.853	7.2	137.6	144.8	51	51
TOTALS	15 Hrs.							
AVERAGES...		2.08004	1.91996	7.75	118.93	126.68	43.1	44.2

TABLE 1.—Continued.

SOUTH ENGINES—FIRST TRIAL.

DATE.	TIME.	WATER LEVELS + P. R.					PRESSURES.	
DECEMBER.		Reading of Hook Gauge.	Depth of Water on Weir.	In Pump Well.	In Stand Pipe.	Head against Pumps.	Gauge on South Pump Main.	Gauge on North Pump Main.
1874.	H. M.	Feet.	Feet.	Feet.	Feet.	Feet.	Pounds.	Pounds.
1	2.	21.	22.	23.	24.	25.	26.	27.
				—	+			
11th.	10 P. M.	2.147	1.853	9.2	141.0	148.2	53	53
	10.30	2.095	1.905	7.0	141.1	148.1	53	54
	11.00	2.050	1.950	6.8	145.4	152.2	53	54
	11.30	1.915	2.085	6.4	145.4	151.8	55	56
12th.	12.00	1.980	2.020	6.8	145.4	152.2	53	54
	12.30	1.836	2.164	6.0	141.0	147.0	54	54
	1.00	1.765	2.235	5.7	142.0	147.7	53	54
	1.30	1.780	2.220	5.7	138.0	143.7	54	55
	2.00	2.123	1.877	6.9	140.3	147.2	53	54
	2.30	2.174	1.826	7.2	140.0	147.2	52	54
	3.00	2.037	1.963	6.6	143.0	149.6	54	56
	3.30	2.096	1.904	7.3	145.4	152.7	54	54
	4.00	2.086	1.914	8.3	145.4	153.7	54	55
	4.30	2.013	1.987	8.6	145.4	154.0	53	55
	5.00	2.008	1.992	8.5	145.4	153.9	53	55
	5.30	2.005	1.995	9.2	137.0	146.2	50	54
	6.00	2.105	1.895	7.3	141.0	148.3	52	54
TOTALS	8½ Hrs.							
AVERAGES....		2.0133	1.9867	7.1	142.5	149.6	53.1	54.4
	6.30	2.095	1.905	— 8.0	+ 134.8	142.8	50	54
	7.00	2.000	2.000	8.3	123.7	132.0	43	44
	7.30	2.104	1.896	8.1	122.8	130.9	44	45
	8.00	2.001	1.999	8.0	120.0	128.0	44	45
	8.30	1.992	2.008	10.0	114.0	124.0	41	42
	9.00	2.009	1.991	10.0	107.6	117.6	37	38
	9.30	2.003	1.997	9.7	106.8	116.5	37	38
	10.00	1.998	2.002	9.4	107.0	116.4	37	39
	10.30	1.995	2.005	9.3	107.6	116.9	38	39
	11.00	2.010	1.990	9.6	107.7	117.3	38	39
	11.30	2.009	1.991	9.7	108.1	117.8	38	39
	12.00 M.	2.004	1.996	8.8	108.8	117.6	38	39
	12.30	2.007	1.993	9.5	110.0	119.5	38	39
	1.00	2.078	1.922	7.5	110.9	118.4	38	40
	1.30	2.171	1.829	7.2	110.0	117.2	38	40
	2.00	2.100	1.900	7.1	116.0	123.1	40	41
	2.30	2.049	1.951	8.2	113.0	121.2	40	41
	3.00	1.990	2.010	9.4	112.0	121.4	39	40
	3.30	2.003	1.997	9.1	114.7	123.8	40	41
	4.00	2.085	1.915	8.0	115.5	123.5	42	43
	4.30	1.976	2.024	9.2	113.7	122.9	40	43
	5.00	1.987	2.013	8.8	114.0	122.8	40	44
	5.30	2.051	1.949	7.9	121.5	129.4	44	47
	6.00	1.986	2.014	8.7	123.0	131.7	45	48
	6.30	2.097	1.903	7.7	120.0	127.7	48	50
	7.00	2.037	1.963	10.0	118.0	128.0	45	50
	7.30	2.011	1.989	7.5	128.5	136.0	45	50
	8.00	2.115	1.885	8.0	129.5	137.5	50	52
	8.30	2.006	1.994	8.9	130.0	138.9	47	50
	9.00	2.122	1.878	7.8	133.9	141.7	50	54
	9.30	2.004	1.996	9.0	139.9	148.9	48	52
	10.00	1.997	2.003	6.9	143.5	150.4	54	55
TOTALS	16 Hours.							
AVERAGES....		2.003	1.997	8.6	118.3	126.9	42.4	44.4
	50 Hours.			7.53	127.12	134.85	46.5	47.6

TABLE 1.—Continued.

SOUTH ENGINES—FIRST TRIAL.

DATE.	TIME.	SPEED RECORD.			BOILERS.		
					FEED WATER.		
DECEMBER.		Counter Readings.	Revolutions.	Piston Speed per Minute.	Meter Readings.	Cubic Feet Water.	Pounds of Water Evaporated per lb. of coal from 212° Fr.
1874.	H. M.			Feet.			
1.	2.	28.	29.	30.	31.	32.	33.
10th.	8 P. M.	286552	----	------	20535	----	------
	8.30	286856	304	------	20763	228	------
	9.00	287172	316	------	20989	226	------
	9.30	287484	312	------	21206	217	------
	10.00	287808	324	------	21703	497	------
	10.30	288122	314	------	21797	494	------
	11.00	288438	316	209.90	22080	283	------
TOTALS	3 Hours.		1886	209.90		1945	11.952
11th.	11.30	288762	324	------	22849	369	------
	12.00	289070	308	------	23174	325	------
	12.30	289379	309	------	23456	282	------
	1.00	289682	303	------	23709	253	------
	1.30	289993	311	------	24018	309	------
	2.00	290303	310	------	24344	326	------
	2.30	290604	301	------	24674	330	------
	3.00	290943	339	------	25012	338	------
	3.30	291191	248	------	25326	314	------
	4.00	291473	282	------	25586	260	------
	4.30	291750	277	------	25860	274	------
	5.00	292038	288	------	26124	264	------
	5.30	292325	287	------	26384	260	------
	6.00	292625	300	------	26640	256	------
	6.30	292932	307	200.06	26954	314	------
TOTALS	7½ Hrs.		4494	200.06		4474	9.614
	7.00	293252	320	------	27260	306	------
	7.30	293591	339	------	27547	287	------
	8.00	293906	315	------	27856	309	------
	8.30	294222	316	------	28240	384	------
	9.00	294546	324	------	28546	306	------
	9.30	294873	327	------	28816	270	------
	10.00	295199	326	------	29073	257	------
	10.30	295506	307	------	29323	250	------
	11.00	295822	316	------	29605	282	------
	11.30	296133	311	------	29890	285	------
	12.00 M.	296449	316	------	30181	291	------
	12.30	296769	320	------	30472	291	------
	1.00	297082	313	------	30745	273	------
	1.30	297396	314	------	31026	281	------
	2.00	297703	307	------	31301	275	------
	2.30	298025	322	------	31584	283	------
	3.00	298346	321	------	31870	286	------
	3.30	298650	304	------	32180	310	------
	4.00	298975	325	------	32555	375	------
	4.30	299292	317	------	32953	398	------
	5.00	299606	314	------	33343	390	------
	5.30	299920	314	------	33687	344	------
	6.00	300226	306	------	34001	314	------
	6.30	300532	306	------	34266	265	------
	7.00	300848	316	------	34510	244	------
	7.30	301161	313	------	34804	294	------
	8.00	301483	322	------	35138	334	------
	8.30	301800	317	------	35468	330	------
	9.00	302125	325	------	35808	340	------
	9.30	302442	317	211.68	36141	333	------
TOTALS	15 Hours.		9510	211.68		9187	11.502

TABLE 1.—Continued.

SOUTH ENGINES—FIRST TRIAL.

DATE.	TIME.	SPEED RECORD.			BOILERS.		
					FEED WATER.		
DECEMBER.		Counter Readings.	Revolutions.	Piston Speed per Minute.	Meter Readings.	Cubic Feet Water.	Pounds of Water Evap'ratd per pound of Coal.
1874.	H. M.			Feet.			
1.	2.	28.	29.	30.	31.	32.	33.
11th.	10 P. M.	302767	325	------	36470	329	------
	10.30	303086	319	------	36795	325	------
	11.00	303408	322	------	37121	326	------
	11.30	303737	329	------	37447	326	------
12th.	12.00	304079	342	------	37791	344	------
	12.30	304406	327	------	38155	364	------
	1.00	304747	341	------	38555	400	------
	1.30	305066	319	------	38943	388	------
	2.00	305422	356	------	39354	411	------
	2.30	305684	262	------	39626	272	------
	3.00	306026	342	------	39953	327	------
	3.30	306361	335	------	40245	292	------
	4.00	306676	315	------	40517	272	------
	4.30	306997	321	------	40830	313	------
	5.00	307326	329	------	41236	406	------
	5.30	307632	306	------	41604	368	------
	6.00	307958	326	216.67	41929	325	------
TOTALS ------	8½ Hrs.		5,516	216.67		5,788	10.619
	6.30	308286	328	------	42225	296	------
	7.00	308618	332	------	42520	295	------
	7.30	308913	295	------	42770	250	------
	8.00	309219	306	------	43020	250	------
	8.30	309585	366	------	43317	297	------
	9.00	309915	330	------	43590	273	------
	9.30	310232	317	------	43857	267	------
	10.00	310554	322	------	44125	268	------
	10.30	310874	320	------	44409	284	------
	11.00	311196	322	------	44671	262	------
	11.30	311514	318	------	44938	267	------
	12.00 M.	311835	321	------	45205	267	------
	12.30	312154	319	------	45471	266	------
	1.00	312472	318	------	45778	307	------
	1.30	312787	315	------	46128	350	------
	2.00	313108	321	------	46423	295	------
	2.30	313436	328	------	46695	272	------
	3.00	313762	326	------	46969	274	------
	3.30	314080	318	------	47252	283	------
	4.00	314391	311	------	47589	337	------
	4.30	314734	343	------	47954	365	------
	5.00	315064	330	------	48306	352	------
	5.30	315393	329	------	48610	304	------
	6.00	315704	311	------	48885	275	------
	6.30	316038	334	------	49183	298	------
	7.00	316393	355	------	49400	217	------
	7.30	316707	314	------	49700	300	------
	8.00	317008	301	------	50079	379	------
	8.30	317335	327	------	50425	346	------
	9.00	317630	295	------	50787	362	------
	9.30	317956	326	------	51145	358	------
	10.00	318271	315	215.21	51547	402	------
TOTALS ------	16 Hours.		10,313	215.21		9,618	11.803
TOTALS ------	50 Hours.		31,719	211.808		31,012	11.0812

TABLE 1.—Continued.

SOUTH ENGINES—FIRST TRIAL.

DATE.	TIME.	BOILERS.								
		COAL IN POUNDS.					SURFACES.			
DECEMBER.		In each Half Hour.	Per Sq. Feet of Grate surface pr hour.	Pr Indicat'd Horse pow'r per hour.	Per Actual Horse pow'r per hour.	Ashes, Cinders and Clinkers.	Total in Nine Grates	Fire Surface	Inside of Flues.	Inside of Tubes.	Ends.
						Lbs.	Sq. ft.	Sq. ft.	Sq. ft.	Sq. ft.	Sq. ft.
1.	2.	34.	35.	36.	37.	38.	39.	40.	41.	42.	43.
10th.	8.00 P. M.			----	----	----	----	----	----	----	----
	8.30	1,946		----	----	----	----	----	----	----	----
	9.00	2,028	13.25	----	----	----	----	----	----	----	----
	9.30	1.997		----	----	----	----	----	----	----	----
	10.00	2,074	13.57	----	----	----	----	----	----	----	----
	10.30	2,010		----	----	----	----	----	----	----	----
	11.00	2,027	13.45	----	----	1574	300	----	----	----	----
TOTALS	3 Hours.	12,082				1574	300	639	1710	3537	1476
AVERAGES..			13.424								
	11.30	2,316		----	----	----	----	----	----	----	----
11th.	12.00	2,201	15.06	----	----	----	----	----	----	----	----
	12.30	2,208		----	----	----	----	----	----	----	----
	1.00	2,166	14.58	----	----	----	----	----	----	----	----
	1.30	2,222		----	----	----	----	----	----	----	----
	2.00	2,215	14.79	----	----	----	----	----	----	----	----
	2.30	2,151		----	----	----	----	----	----	----	----
	3.00	2,423	15.25	----	----	----	----	----	----	----	----
	3.30	1,772		----	----	----	----	----	----	----	----
	4.00	2,015	12.62	----	----	----	----	----	----	----	----
	4.30	1,980		----	----	----	----	----	----	----	----
	5.00	2,058	13.46	----	----	----	----	----	----	----	----
	5.30	2,051		----	----	----	----	----	----	----	----
	6.00	2,145	13.99	----	----	----	----	----	----	----	----
	6.30	2,195	7.32	----	----	4185	300	----	----	----	----
TOTALS	7½ Hours.	32,118				4185	300	639	1710	3537	1476
AVERAGES..			14.276								
	7.00	1,852		----	----	----	----	----	----	----	----
	7.30	1,961	12.71	----	----	----	----	----	----	----	----
	8.00	1,823		----	----	----	----	----	----	----	----
	8.30	1,829	12.17	----	----	----	----	----	----	----	----
	9.00	1,875		----	----	----	----	----	----	----	----
	9.30	1,892	12.56	----	----	----	----	----	----	----	----
	10.00	1,887		----	----	----	----	----	----	----	----
	10.30	1,777	12.21	----	----	----	----	----	----	----	----
	11.00	1,829		----	----	----	----	----	----	----	----
	11.30	1,801	12.10	----	----	----	----	----	----	----	----
	12.00 M.	1,829		----	----	----	----	----	----	----	----
	12.30	1,852	12.27	----	----	----	----	----	----	----	----
	1.00	1,813		----	----	----	----	----	----	----	----
	1.30	1,818	12.10	----	----	----	----	----	----	----	----
	2.00	1,777			----	----	----	----	----	----	----
	2.30	1,864	12.14		----	----	----	----	----	----	----
	3.00	1,859		2.98	4.86	----	----	----	----	----	----
	3.30	1,760	12.06		----	----	----	----	----	----	----
	4.00	1,881			----	----	----	----	----	----	----
	4.30	1,835	12.39	----	----	----	----	----	----	----	----
	5.00	1,818		----	----	----	----	----	----	----	----
	5.30	1,818	12.12	----	----	----	----	----	----	----	----
	6.00	1,772		----	----	----	----	----	----	----	----
	6.30	1,772	11.81	----	----	----	----	----	----	----	----
	7.00	1,829		----	----	----	----	----	----	----	----
	7.30	1,813	12.14	----	----	----	----	----	----	----	----
	8.00	1,864		----	----	----	----	----	----	----	----
	8.30	1,835	12.33	----	----	----	----	----	----	----	----
	9.00	1,881		----	----	----	----	----	----	----	----
	9.30	1,835	12.39	----	----	7173	300	----	----	----	----
TOTALS	15 Hours.	55,051				7173	300	639	1710	3537	1476
AVERAGES..			12.233								

TABLE 1.—Continued.

SOUTH ENGINES—FIRST TRIAL.

DATE.	TIME.	BOILERS.									
		COAL IN POUNDS.					SURFACES.				
DECEMBER.		In each Half Hour.	Per Square Feet of Grate Surface per Hour.	Per Indicated Horse-Power per Hour.	Per Actual Horse-Power per Hour.	Ashes, Cinders, and Clinkers.	Total in Nine Grates.	Fire Surface.	Inside of Flues.	Inside of Tubes.	Ends.
1874.	H. M.					Lbs.	Sq. ft.	Sq. ft.	Sq. ft.	Sq. ft.	Sq.f
1.	2.	34.	35.	36.	37.	38.	39.	40.	41.	42.	43.
11th.	10 P. M.	2,205				----	----	----	----	----	----
	10.30	2,164	14.56			----	----	----	----	----	----
	11.00	2,184				----	----	----	----	----	----
	11.30	2,231	14.72	3.23	4.48	----	----	----	----	----	----
12th.	12.00	2,320				----	----	----	----	----	----
	12.30	2,218	15.13			----	----	----	----	----	----
	1.00	2,313				----	----	----	----	----	----
	1.30	2,164	14.92	----	----	----	----	----	----	----	----
	2.00	2,414		----	----	----	----	----	----	----	----
	2.30	1,777	13.97	----	----	----	----	----	----	----	----
	3.00	2,320		----	----	----	----	----	----	----	----
	3.30	2,274	15.31	----	----	----	----	----	----	----	----
	4.00	2,136		----	----	----	----	----	----	----	----
	4.30	2,177	14.38	----	----	----	----	----	----	----	----
	5.00	2,231		----	----	----	----	----	----	----	----
	5.30	2,076	14.36	----	----	----	----	----	----	----	----
	6.00	2,218	7.39	----	----	4,875	300	----	----	----	----
TOTALS	8½ Hrs.	37,419				4,875	300	639	1710	3537	1476
AVERAGES..			14.674								
	6.30	1,783		----	----	----	----	----	----	----	----
	7.00	1,805	11.96	----	----	----	----	----	----	----	----
	7.30	1,604		----	----	----	----	----	----	----	----
	8.00	1,664	10.89	----	----	----	----	----	----	----	----
	8.30	1,990				----	----	----	----	----	----
	9.00	1,795	12.62			----	----	----	----	----	----
	9.30	1,723				----	----	----	----	----	----
	10.00	1,751	11.58			----	----	----	----	----	----
	10.30	1,740				----	----	----	----	----	----
	11.00	1,751	11.63			----	----	----	----	----	----
	11.30	1,729				----	----	----	----	----	----
	12.00 M.	1,745	11.58			----	----	----	----	----	----
	12.30	1,735				----	----	----	----	----	----
	1.00	1,729	11.55			----	----	----	----	----	----
	1.30	1,713				----	----	----	----	----	----
	2.00	1,745	11.53			----	----	----	----	----	----
	2.30	1,783		2.96	4.47	----	----	----	----	----	----
	3.00	1,772	11.85			----	----	----	----	----	----
	3.30	1,729				----	----	----	----	----	----
	4.00	1,661	11.30			----	----	----	----	----	----
	4.30	1,865				----	----	----	----	----	----
	5.00	1,794	12.20			----	----	----	----	----	----
	5.30	1,789				----	----	----	----	----	----
	6.00	1,691	11.60			----	----	----	----	----	----
	6.30	1,816				----	----	----	----	----	----
	7.00	1,930	12.38			----	----	----	----	----	----
	7.30	1,708				----	----	----	----	----	----
	8.00	1,637	11.15			----	----	----	----	----	----
	8.30	1,778				----	----	----	----	----	----
	9.00	1,604	11.27	----	----	----	----	----	----	----	----
	9.30	1,772		----	----	----	----	----	----	----	----
	10.00	1,720	11.64	----	----	7,306	300	----	----	----	----
TOTALS	16 Hrs.	56,081				7,306	300	639	1710	3537	1476
AVERAGES..			11.683								
TOTALS	50 Hrs.	192,751	12.445			25,113	300	639	1710	3537	1476

TABLE 1.—Continued.

SOUTH ENGINES—FIRST TRIAL.

DATE.	TIME.	U. S. GALLONS WATER PUMPED, AS MEASURED BY			U. S. Gallons of Water Elevated 150 Ft. per 24 Hours by Weir Measurement.	DUTY.		
DEC.		Tunnel Formula.	Weir Formula.	Calculat'd Pump Capacity.		First Method in Foot-Lbs. per 100 Pounds of Coal.	Second Method in Foot-Lbs. per 100 Pounds of Coal.	Third method in Foot-Lbs. per 100 lbs. of Coal.
1874.	H. M.							
1.	2.	44.	45.	46.	47.	48.	49.	50.
10th.	8 P. M.							
	8.30	720,945	745,037	811,376	------	------	------	
	9.00	757,207	745,037	843,404	------	------	------	
	9.30	756,133	768,472	832,728	------	------	------	
	10.00	764,739	689,125	864,756	------	------	------	
	10.30	762,038	717,185	838,066	------	------	------	
	11.00	749,102	719,764	843,404	------	------	------	
TOTALS	3 Hrs.	4,510,164	4,384,620	5,033,734	33,206,189	42,978,025	53,550,241	
11th.	11.30	752,375	696,892	864,756	------	------	------	
	12.00	750,983	737,036	822,052	------	------	------	
	12.30	744,331	722,639	824,721	------	------	------	
	1.00	734,967	720,918	808,707	------	------	------	
	1.30	742,238	697,994	830,059	------	------	------	
	2.00	738,783	783,249	827,390	------	------	------	
	2.30	732,933	745,037	803,369	------	------	------	
	3.00	738,189	745,037	904,791	------	------	------	
	3.30	682,911	745,037	661,912	------	------	------	
	4.00	685,387	745,037	752,658	------	------	------	
	4.30	681,190	745,037	739,313	------	------	------	
	5.00	691,455	745,037	768,672	------	------	------	
	5.30	699,171	745,037	766,003	------	------	------	
	6.00	728,661	745,037	800,700	------	------	------	
	6.30	744,918	745,037	819,383	------	------	------	
TOTALS	7½ Hrs.	10,847,592	11,064,061	11,994,486	34,911,685	42,494,199	49,696,789	
	7.00	771,779	777,345	854,080	------	------	------	
	7.30	767,414	774,973	904,791	------	------	------	
	8.00	763,184	769,676	840,735	------	------	------	
	8.30	771,860	739,265	843,404	------	------	------	
	9.00	775,882	681,173	864,756	------	------	------	
	9.30	776,443	689,612	872,763	------	------	------	
	10.00	759,581	766,746	870,094	------	------	------	
	10.30	764,166	708,344	819,383	------	------	------	
	11.00	769,031	712,900	843,404	------	------	------	
	11.30	771,537	704,348	830,059	------	------	------	
	12.00 M.	765,798	727,233	843,404	------	------	------	
	12.30	761,137	744,023	854,080	------	------	------	
	1.00	780,695	686,791	835,397	------	------	------	
	1.30	776,283	762,038	838,066	------	------	------	
	2.00	762,856	767,919	819,383	------	------	------	
	2.30	774,920	679,388	859,418	------	------	------	
	3.00	781,096	693,001	856,749	------	------	------	
	3.30	772,749	746,280	811,376	------	------	------	
	4.00	770,162	736,430	867,425	------	------	------	
	4.30	777,888	681,729	846,073	------	------	------	
	5.00	765,393	757,983	838,066	------	------	------	
	5.30	768,465	681,173	838,066	------	------	------	
	6.00	757,663	738,131	816,714	------	------	------	
	6.30	751,666	768,614	816,714	------	------	------	
	7.00	762,447	710,047	843,404	------	------	------	
	7.30	769,678	680,063	835,397	------	------	------	
	8.00	764,494	768,473	859,414	------	------	------	
	8.30	768,384	703,391	846,073	------	------	------	
	9.00	759,827	736,430	867,425	------	------	------	
	9.30	770,648	687,354	846,073	------	------	------	
TOTALS	15 Hrs.	23,055,126	21,780,873	25,382,190	29,354,809	41,691,869	52,986,695	

TABLE 1.—Continued.

SOUTH ENGINES—FIRST TRIAL.

DATE.	TIME.	U. S. GALLONS WATER PUMPED, AS MEASURED BY			U. S. Gallons of Water Elevated 150 Feet per Twenty-four Hours by Weir Measurement.	DUTY.		
DECE.		Tunnel Formula.	Weir Formula.	Calculat'd Pump Capacity.		First Method in Foot-Lbs. per 100 Pounds of Coal.	Second Method in Foot-Lbs. per 100 Pounds of Coal.	Third Method in Foot-Lbs per 100 Pounds of Coal.
1874.	H. M.							
1.	2.	44.	45.	46.	47.	48.	49.	
11th.	10 P. M	771,052	687.354	867,425	------	------	------	------
	10.30	769,273	716,941	851,411	------	------	------	------
	11.00	771,618	742,865	859,418	------	------	------	------
	11.30	762,201	822,639	878,101	------	------	------	------
12th.	12.00	771,456	783,837	912,798	------	------	------	------
	12.30	762,283	870,608	872,763	------	------	------	------
	1.00	750,343	914,629	910,129	------	------	------	------
	1.30	745,588	905,264	851,411	------	------	------	------
	2.00	742,991	701,497	950,164	------	------	------	------
	2.30	741,400	672,249	699,278	------	------	------	------
	3.00	759,418	750,410	912,798	------	------	------	------
	3.30	740,982	716,372	894,115	------	------	------	------
	4.00	750,922	722,064	840,735	------	------	}	
	4.30	758,026	764,282	856,749	------	------		
	5.00	758,189	767,327	878,101	------	------		64,246,901
	5.30	761,628	768,614	816,714	------	------		
	6.00	772,264	711,198	870,094	------	------	}	
TOTALS	8½ Hrs.	12,889,634	13,018,150	14,722,204	36,659,110	43,406,497	52,879,717	
	6.30	778,850	716,949	875,432	------	------	------	------
	7.00	774,599	772,018	886,108	------	------	------	------
	7.30	781,336	711,759	787,355	------	------	------	------
	8.00	769,758	771,430	816,714	------	------	------	------
	8.30	767,576	776,748	976,854	------	------	------	------
	9.00	756,546	766,747	880,770	------	------	------	------
	9.30	757,862	770,256	846,073	------	------	------	------
	10.00	765,798	773,198	859,418	------	------	------	------
	10.30	766,444	774,973	854,080	------	------	------	------
	11.00	761,710	766,159	859,418	------	------	------	------
	11.30	760,564	766,747	848,742	------	------	------	------
	12.00M	757,125	769,676	856,749	------	------	------	------
	12.30	756,629	767,919	851,411	------	------	------	------
	1.00	770,809	726,660	848,742	------	------	------	------
	1.30	773.315	673,909	840,735	------	------	------	------
	2.00	774,599	714,042	856,749	------	------	------	------
	2.30	770,809	743,445	875,432	------	------	------	------
	3.00	764,494	777,931	870,094	------	------	------	------
	3.30	764,166	770,256	848,742	------	------	------	------
	4.00	781,449	722,640	830,059	------	------	------	------
	4.30	775,000	783,249	915,467	------	------	------	------
	5.00	777,807	779,697	880,770	------	------	------	------
	5.30	780,695	742,109	878,101	------	------	------	------
	6.00	781,256	780,086	830,059	------	------	------	------
	6.30	784,432	715,760	891,446	------	------	------	------
	7.00	782,369	750,041	947,495	------	------	------	------
	7.30	780,213	765,572	838,066	------	------	------	------
	8.00	786,338	705,494	803,369	------	------	}	
	8.30	781,892	768,473	872,763	------	------		78,008,421
	9.00	789,037	701,501	787,355	------	------		
	9.30	787,211	769,676	870,094	------	------	------	------
	10.00	784,354	773,789	840,735	------	------	------	------
TOTALS	16 Hrs.	24,751,032	24,068,900	27,525,397	30,543,434	45,422,179	56,943,959	
TOTALS	50 Hrs.	76,053,548	75,316,604	84,658,011	32,452,780	43,880,476	54,025,762	

TABLE 2.

SOUTH ENGINES — SECOND TRIAL.

DATE.	TIME.	PRESSURES.					TEMPERATURES—DG. FH.					
DECEMBER.		Aneroid Barometer.	Vacuum Gauge.	*Steam in Boilers.	Steam in Steam Pipe.	Water Gauge at Engine.	Open Air.	Engine Room.	Boiler Room.	Water in Pump Well.	Boiler Feed Water.	Steam near Throttle Valve.
1874.	H. M.	Inches.	In.	Lbs.	Lbs.	Lbs.						
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
	P. M.					+						
14th.	12.30	30.05	26.5	24	23	38	25	71	73		122	----
	1.00	30.03	26.5	28	30	48	25	72	70	33	120	----
	1.30	30.03	26.5	29	30	48	25	73	73		120	----
	2.00	30.02	26.5	29	30	48	24	73	77	33	117	----
	2.30	30.02	26.5	28	29	48	24	73	74		117	----
	3.00	30.02	26.5	29	30	49	24	73	74	33	117	----
	3.30	30.03	27.0	29	30	50	24	73	75		115	----
	4.00	30.03	26.5	29	30	51	24	73	77	33	116	----
	4.30	30.05	26.5	29	30	50	23	73	78		117	----
	5.00	30.05	26.5	29	30	49	22	73	79	33	120	----
	5.30	30.05	26.5	29	31	51	22	72	78		120	----
TOTALS	5 Hrs.											
AVERAGES..		30.034	26.55	28.4	28.5	48.2	22.8	72.6	75.3	33	118.3	----
	6.00	30.06	26.5	29	30	51	21	72	76	33	119	----
	6.30	30.05	26.5	26	30	50	21	72	75		118	----
	7.00	30.05	26.0	26	30.5	50	21	72	76	33	120	----
	7.30	30.05	26.0	26	30.5	50	20	71	74		120	----
	8.00	30.05	26.5	26	31	50	20	71	74		118	----
	8.30	30.05	26.5	25	29.5	49	20	71	73	33	116	----
	9.00	30.05	26.5	26	30	50	20	72	74		117	----
	9.30	30.04	26.5	27	30	50	21	71	74	33	118	----
TOTALS	4 Hrs.											
AVERAGES..		30.05	26.4	26.4	30.2	50	20.5	71.5	74.5	33	118.25	----
	10.00	30.04	26.0	27	31	53	21	72	76		116	----
	10.30	30.04	26.5	27	30	54	20	72	76		118	----
	11.00	30.03	26.0	27	31	54	20	72	79	33	118	----
	11.30	30.03	26.0	26	31	55	20	71	79		117	----
15th.	12.00	30.03	26.0	27	31	53	20	70	75		120	----
	12.30	30.02	27.0	27	30	54	21	70	73	33	118	----
	1.00	30.00	26.5	27	30	54	20	70	73	33	116	----
	1.30	30.00	26.0	27	30	54	20	70	73	33	115	----
TOTALS	4 Hrs.											
AVERAGES..		30.024	26.25	*26.9	30.5	53.9	20.3	70.9	75.5	33	117.25	----
TOTALS	13 Hrs.											
AVERAGES..		30.037	26.41	27.29	29.64	50.41	21.3	71.74	75.11	33	118	

* Gauge out of order.

TABLE 2.—Continued.

SOUTH ENGINES—SECOND TRIAL.

DATE.	TIME.	WATER LEVELS + P. R.						PRES'URS.	
DECEMBER.		Lake Shaft 1st Tunnel.	Land Shaft 1st Tunnel.	Fall Betw'n Lake and Land Shaft.	In Pump Well.	In Stand Pipe.	Head against Pumps.	Gauge on South Pump Main.	Gauge on North Pump Main.
1874.	H. M.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Lbs.	Lbs.
1.	2.	14.	15.	16.	17.	18.	19.	20.	21.
	P. M.				—	+			
14th.	12.30	+	—		4.2	118.0	122.2	39	39
	1.00	1.096	4.510	5.606	5.9	127.0	132.9	48	48
	1.30	1.113	4.733	5.846	6.0	130.0	136.0	47	48
	2.00	1.143	4.816	5.959	5.8	130.3	136.1	48	49
	2.30	1.043	4.663	5.706	5.7	129.0	134.7	48	48
	3.00	1.086	4.603	5.689	5.6	130.4	136.0	49	50
	3.30	1.230	4.423	5.653	5.2	132.0	137.2	49	50
	4.00	1.130	4.483	5.613	5.5	131.0	136.5	49	50
	4.30	0.973	4.803	5.776	5.9	131.0	136.9	49	49
	5.00	1.000	4.773	5.773	5.8	131.8	137.6	49	50
	5.30	1.120	4 653	5.773	5.7	131.9	137.6	49	50
TOTALS	5 Hrs.								
AVERAGES....		1.093	4.646	5.739	5.5	129.3	134.8	47.6	48.4
	6.00	1.073	4.426	5.499	5.4	133.7	139.1	51	51
	6.30	1.080	4.243	5.323	5 3	137.0	142.3	50	52
	7.00	1.140	4.220	5.360	4.8	133.4	138.2	49	53
	7.30	1.023	3.883	4.906	4.8	135.0	139.8	49	53
	8.00	1.030	4.026	5.056	4.7	135.3	140.0	50	50
	8.30	0.980	3.856	4.836	4.6	137.0	141.6	50	53
	9.00	1.033	3.860	4.893	4.8	139.2	144.0	51	53
	9.30	1.053	3.810	4.863	4.7	139.2	143.9	53	54
TOTALS	4 Hrs.								
AVERAGES....		1.052	4.040	5.092	4.9	136.2	141.1	50.4	52.4
	10.00	1.093	3.776	4.869	4.8	145.4	150.2	53	55
	10.30	1.046	3.803	4.849	4.8	145.4	150.2	54	55
	11.00	1.063	4.036	5.099	5.0	145.4	150.4	54	55
	11.30	0.920	4.180	5.100	5.3	145.4	150.7	54	56
15th.	12.00	0.786	4.060	4.846	5.5	145.4	150.9	53	55
	12.30	0.940	3.726	4.666	4.5	145.4	149.9	52	53
	1.00	0.880	3.530	4.410	4.3	145.4	149.7	54	55
	1.30	0.946	3.480	4.426	4.3	145.4	149.7	54	54
TOTALS	4 Hrs.								
AVERAGES....		0.959	3.824	4.783	4.8	145.4	150.2	53.5	54.8
TOTALS	13 Hrs.								
AVERAGES....		1.039	4.207	5.246	5.144	136.38	141.48	50.3	51.6

TABLE 2.—Continued.

SOUTH ENGINES—SECOND TRIAL.

DATE.	TIME.	SPEED RECORD.			BOILERS.		
					FEED WATER.		
DECEMBER.		Counter Readings.	Revolutions.	Piston Speed per Minute.	Meter Readings.	Cubic Feet Water.	Pounds of Water Evaporated per Pound of Coal.
1874.	H. M.			Feet.			
1.	2.	22.	23.	24.	25.	26.	27.
	P. M.						
14th.	12.30	320402	---	------	53460	---	----
	1.00	320772	370	------	53700	240	----
	1.30	321141	369	------	54028	328	----
	2.00	321513	372	------	54376	348	----
	2.30	321871	358	------	54720	344	----
	3.00	322217	346	------	55084	364	----
	3.30	322555	338	------	55434	350	----
	4.00	322899	344	------	55768	334	----
	4.30	323247	348	------	56074	306	----
	5.00	323597	350	------	56377	303	----
	5.30	323944	347	240.0295	56677	300	----
TOTALS	5 Hours.		3542	240.0295		3217	8.906
	6.00	324284	340	------	57000	323	----
	6.30	324620	336	------	57321	321	----
	7.00	324948	328	------	57625	304	----
	7.30	325272	324	------	57945	320	----
	8.00	325605	333	------	58286	341	----
	8.30	325917	312	------	58585	299	----
	9.00	326233	316	------	58846	261	----
	9.30	326535	302	219.479	59124	278	----
TOTALS	4 Hours.		2591	219.479		2447	9.658
	10.00	326872	337	------	59439	315	----
	10.30	327220	348	------	59740	301	----
	11.00	327541	321	------	60026	286	----
	11.30	327865	324	------	60327	301	----
15th.	12.00	328204	339	------	60645	318	----
	12.30	328536	332	------	60975	330	----
	1.00	328840	304	------	61288	313	----
	1.30	329121	281	219.055	61567	279	----
TOTALS	4 Hours.		2586	219.055		2443	9.927
TOTALS	13 Hours.		8719			8107	
AVERAGES....				227.253			9.42

TABLE 2.—Continued.

SOUTH ENGINES—SECOND TRIAL.

DATE.	TIME.	BOILERS.									
		COAL IN POUNDS.					SURFACES.				
DECEMBER.		In Each Half Hour.	Per Square Feet Grate Surface per Hour.	Per Indicated Horse-Power per Hour.	Per Actual Horse-Power per Hour.	Ashes, Cinders and Clinkers.	Total in Nine Grates	Fire Surface.	Inside of Flues.	Inside of Tubes.	Ends.
1874.	H. M.						Sq. ft.	Sq. ft.	Sq.f	Sq.f	Sq.f
1.	2.	28.	29.	30.	31.	32.	33.	34.	35.	36.	37.
	P. M.										
14th.	12.30	----	----	----	----	----	300	----	----	----	----
	1.00	2579	----	----	----	----	----	----	----	----	----
	1.30	2573	17.17	----	----	----	----	----	----	----	----
	2.00	2593	----			----	----	----	----	----	----
	2.30	2495	16.96			----	----	----	----	----	----
	3.00	2412	----			----	----	----	----	----	----
	3.30	2356	15.89	3.27	4.91	----	----	----	----	----	----
	4.00	2400	----			----	----	----	----	----	----
	4.30	2426	16.09			----	----	----	----	----	----
	5.00	2440	----			----	----	----	----	----	----
	5.30	2421	16.20			2534	----	----	----	----	----
TOTALS....	5 Hrs.	24695				2534	300	639	1710	3537	1476
AVERAGES..			16.463								
	6.00	2275	----			----	300	----	----	----	----
	6.30	2248	15.08	3.27	4.91	----	----	----	----	----	----
	7.00	2195	----			----	----	----	----	----	----
	7.30	2168	14.54	----	----	----	----	----	----	----	----
	8.00	2228	----	----	----	----	----	----	----	----	----
	8.30	2088	14.39	----	----	----	----	----	----	----	----
	9.00	2114	----	----	----	----	----	----	----	----	----
	9.30	2025	13.79	----	----	1780	----	----	----	----	----
TOTALS	4 Hrs.	17341				1780	300	639	1710	3537	1476
AVERAGES..			14.450								
	10.00	2197	----	----	----	----	300	----	----	----	----
	10.30	2269	14.89	----	----	----	----	----	----	----	----
	11.00	2093	----	----	----	----	----	----	----	----	----
	11.30	2113	14.02	----	----	----	----	----	----	----	----
15th.	12.00	2210	----	----	----	----	----	----	----	----	----
	12.30	2165	14.58	----	----	----	----	----	----	----	----
	1.00	1982	----	----	----	----	----	----	----	----	----
	1.30	1835	12.72	----	----	1731	----	----	----	----	----
TOTALS	4 Hrs.	16864				1731	300	639	1710	3537	1476
AVERAGES..			14.053								
TOTALS	13 Hrs.	58900				6045	300	639	1710	3537	1476
AVERAGES..			15.1								

TABLE 2.—Continued.

SOUTH ENGINES—SECOND TRIAL.

DATE.	TIME.	U. S. GALLONS OF WATER PUMPED AS MEASURED BY		U. S. Gallons of Water Elevated 150 Feet per Twenty-four Hours Reduced to Weir Measurement.	DUTY.		
DECEMBER.		Tunnel Formula.	Calculat'd Pump Capacity.		First Method in Foot-Lbs. per 100 lbs of Coal.	Second Method in Foot-Lbs. per 100 lbs of Coal.	Third Method in Foot-Lbs. per 100 lbs of Coal.
1874.	H. M.						
1.	2.	38.	39.	40.	41.	42.	43.
	P. M.						
14th.	12.30	------	------	------	------	------	------
	1.00	835,821	987,530	------	------	------	------
	1.30	853,510	984,861	------	------	------	------
	2.00	861,723	992,868	------	------		
	2.30	843,233	955,502	------	------		
	3.00	841,973	923,447	------	------		
	3.30	839,296	902,122	------	------		59,370,793
	4.00	836,321	918,136	------	------		
	4.30	848,381	928,812	------	------		
	5.00	848,160	934,150	------	------		
	5.30	848,160	926,143	------	------	------	------
TOTALS ------	5 Hrs.	8,456,578	9,453,598	35,748,729	37,864,755	47,398,218	
	6.00	827,799	907,460	------	------		
	6.30	814,441	896,784	------	------		
	7.00	817,263	875,432	------	------		
	7.30	781,893	864,756	------	------		62,385,211
	8.00	793,753	888,777	------	------		
	8.30	776,283	832,728	------	------		
	9.00	780,855	843,404	------	------		
	9.30	778,449	806,038	------	------		
TOTALS ------	4 Hrs.	6,370,736	6,915,379	35,237,305	42,367,673	50,558,269	
	10.00	778,930	899,452	------	------		
	10.30	777,326	928,812	------	------		
	11.00	797,047	856,749	------	------		
	11.30	797,288	864,756	------	------		65,923,624
15th.	12.00	777,085	904,791	------	------		
	12.30	762,529	886,108	------	------		
	1.00	741,317	811,376	------	------		
	1.30	742,655	749,989	------	------	------	------
TOTALS ------	4 Hrs.	6,174,177	6,902,034	36,352,578	44,944,824	54,929,102	
TOTALS ------	13 Hrs.	21,001,489	23,271,011			50,485,403	
AVERAGES ---				35,838,336	41,230,820		

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APPENDIX.

SOUTH ENGINES.

A pair of beam and fly-wheel engines, standing side by side, and consisting each of a steam and pump cylinder, placed vertically, the former over the latter, at one end of the beam. The other end of the beam is connected, by means of rod and crank, with one end of the shaft of a fly-wheel, common to both engines, and also works the air-pump. Each engine beam is supported, in the centre, upon a single cast-iron column. This column rests upon stone masonry, and is divided into two sections, the lower section constituting the condenser, and the upper the air-vessel, each for its own engine.

The steam valves are double, balanced poppet valves, and the valve gear has a Sickles cut-off attached.

The air pumps are of the ordinary single-acting kind.

There is a single fly-wheel located between the engines (twenty-five feet in diameter, and weighing thirty-three tons), with a crank on each end of its shaft, by means of which, through the beams, the two engines are coupled.

The pumps are of the variety known as bucket (?) and plunger pumps, with no valve in the bucket, however, but, instead of this (the usual device), there are a number of small valves placed in an annular space surrounding the working barrel of the bucket (?).

The principal dimensions of the engines are as follows:

North steam cylinder, 70 inches in diameter.

Stroke of piston, 10.014 feet; Crank, 5.011⅓ feet.

South steam cylinder, 70 inches in diameter.

Stroke of piston, 10.019 feet; Crank, 5.011 feet.

Piston rods above pistons, 7⅞ inches in diameter.

Piston rods below pistons, 8¼ inches in diameter.

Clearance, upper end, 0.04423 times, and

Clearance, lower end, 0.04463 times the volume of the cylinders.

One steam pipe from boilers supplying both cylinders, 26 inches in diameter.

Air-pump cylinder, 45 inches in diameter.

Stroke of piston, 4 feet 6⅛ inches.

Piston rod, 5 inches in diameter.

North pump cylinder, lower end, 57.048 in. in diameter.

North pump cylinder, middle, 57.168 in. in diameter.

North pump plunger, 40 inches in diameter.

South pump cylinder, lower end, 57.144 in. in diameter.

South pump cylinder, middle, 57.216 in. in diameter.

South pump plunger, 40 inches in diameter.

Each pump has fifteen double-beat foot or receiving valves, of 12⅜ inches and 15$\frac{11}{16}$ inches, largest and smallest diameters of valve seats; twelve double-beat delivering valves in annular space around pump barrel, of the same dimensions as the foot valves; and one 36 inch check valve, located in a chamber immediately upon the discharge nozzle from the pump.

From the check valve chamber there is a 36 inch discharge pipe (one from each pump), 80 feet long, terminating in a 36″ by 36″ by 36″ Y pipe. From this Y pipe a 36 inch main leads to the city. This main at fifty feet distant from the Y, has a 30 inch branch connecting it with the stand-pipe.

BOILERS.

There are three flue and tubular boilers, 20 ft. long each.

Shells 12 feet in diameter, and fronts 13 by 13½ feet.

Three grates in each boiler, 4.444 feet wide 7.5 feet long, making 100 square feet grate surface to each boiler.

One flue, 3.75 feet diameter; two flues, 25 inches diameter; six flues, 17¼ inches diameter; sixty-six tubes, 5 inches diameter; and uptake 4 feet diameter. Total heating surface to each boiler, 2,454 square feet.

EXPLANATION OF TABLES.

Column 3, in Tables I and II.—The barometer readings are to be corrected by deducting 0.228 of an inch, the error found by comparing the aneroid barometer used with the government standard barometer at the office of the Signal Service, U. S. A., at Chicago.

Column 13, Table I.—The thermometer, with which the temperature of the steam was taken, was, evidently, incorrect; and, as it was accidentally broken, before removing it from the pipe, there was no opportunity to ascertain the correction for reducing the readings.

Columns 26 and 27, Table I, and Columns 20 and 21, Table II.—These gauges (although they had been tested) proved wholly unreliable, inasmuch as they did not indicate sufficient pressure to represent the static head; they should have indicated the pressure due the latter plus the friction.

Column 34, Table I, and Column 28, Table II.—The rate of coal consumption was correctly ascertained for the different periods into which the trials have been divided, and then proportioned for the half hourly divisions of time, according to the number of revolutions made by the engines in each half hour.

Column 33, Table I, and Column 27, Table II.—The number of pounds of water evaporated, per pound of coal, or, more correctly, the feed water supplied to the boilers, is reduced from the initial temperature to an equivalent evaporation from the common standard (212° Fahr.) temperature, by Rankine's formula (see Manual of the Steam Engine, page 254). About seventy-three (73) per cent., on an average, of this feed water, or evaporation, is accounted for by the steam cards during such portions of the trials as they represent.

The balance is to be accounted for by the steam used

in the donkey feed pump, condensation, leakage, and water carried over with the steam.

Column 36, Table I, and Column 30, Table II.—The coal per horse-power per hour, given in these columns, is calculated from the steam cards for such portions of the trials only as they cover.

Column 37, Table I, and Column 31, Table II.—The coal, per horse-power, per hour, given in these columns, is calculated from the quantity of water pumped, as determined by weir gauging and tunnel formula, and the height equivalent to which the water was elevated, as indicated by the height of water in the stand-pipe.

Column 44, Table I, and Column 38, Table II.—The quantities of water given in these columns were calculated by the formula used in determining the flow of water in the lake tunnel.

Column 45, Table I.—The quantities of water given in this column were calculated by Mr. Francis' weir formula. The weir was 6.015 feet long, had no end contraction, and the net cross section of the channel of approach, or flume, was 54 square feet.

Column 46, Table I, and Column 39, Table II.—The quantities of water given in these columns represent the quantities due the areas of the pump pistons multiplied by their travel.

The difference between the quantities in these columns and the quantities given by weir gauging or by tunnel formula, show the loss of action of the pumps, arising from leaks through valves and piston packing, and by the admission of air.

Column 49, Table I, and Column 42, Table II.—In calculating the duty by the second method, the load upon the pump pistons was determined by the sum of the following pressures:

1st. The pressure indicated by the gauge at the engine register. (See column 7, tables I and II.)

2d. The pressure due the height of the gauge above the water in the well. Being the pressure due to 27.774 feet, the height of the gauge above the plane of reference (city datum), and the distance from plane of reference to the water in the well. (See column 23, table I, and column 17, table II.)

3d. Three (3) pounds for friction through the pipes and bends (exclusive of pumps) between the well and the point where the gauge was connected with the pump main.

The following table gives the pump loads, per square inch of piston, for the several periods into which the trials are divided:

TABLE.

Period Ending.	Pressure by Gauge.	Pressure from Gauge to P. R.	Pressure from P. R. to Water in Well.	Pressure due Friction.	Load per Square Inch of Pump Piston.	Length of Period.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Hrs.
Dec. 10, 11 P. M.....	50.00	10.74	3.03	3.0	66.77	3
" 11, 6:30 A. M...	53.00	10.74	2.39	3.0	69.13	7½
" 11, 9:30 P. M...	42.60	10.74	3.36	3.0	59.70	15
" 12, 6:00 A. M...	53.00	10.74	3.08	3.0	69.82	8½
" 12, 10:00 P. M..	42.80	10.74	3.73	3.0	60.27	16
Average.....	46.49	10.74	3.26	3.0	63.49	50
Dec. 14, 5:30 P. M...	48.00	10 74	2.83	3.0	64.32	5
" 14, 9:30 P. M...	50.00	10.74	2.12	3.0	65.86	4
" 15, 1:30 A. M...	53.90	10.74	2.08	3.0	69.72	4
Average.....	50.41	10.74	2 23	3.0	66.38	13

Column 50, Table I, and Column 43, Table II.—The duty, by the third method, is calculated from the pressures of the indicator cards, of which the following is a tabulated statement:

The pressures represented by these cards were believed to be greater than the actual pressures in the pumps. The indicator springs, with which these cards were taken, were, on this account, sent to the American Steam Gauge Company, tested, and found correct; the cards are, therefore, taken as correctly representing the pressures in the pumps.

It will, however, be observed, that there is great irregularity in the pressures represented by the pump cards. This is due, principally, to the constant variation in the speed of the Engines, which variation was produced in this way.

The flow of water over the weir into the well was approximately uniform, but the consumption of water in the city tended to constant irregularity, which tendency produced continual changes in the head against the pumps. The extent of these changes is fairly represented in column 25, Table I, and column 19, Table II; but the frequency of said changes was greater than at half hourly intervals. The steam pressure in the boilers was kept nearly uniform, and the Engines were run with open throttles. The grade of cut-off (see column 9, Table IV,) was adjusted by hand, but not frequently.

Under these conditions, there was nearly a uniform application of power (when prriods less than an hour are considered), water to be pumped out of the well at nearly a uniform rate, against a constantly variable head or resistance; all combining to produce continual variation in speed. But the capacity of the pump-well — less than one and a half minutes' supply for the pumps, when the water stood as high in the well as efficient Weir gauging would permit it to stand — would not allow much variation of speed, unless the pump delivery per revolution could also be varied, and thereby make the quantity pumped correspond in uniformity with the flow of water

into the well. This latter point (variation in quantity of water delivered per revolution,) was attained by admitting more or less air into the pumps, as the height of water in the well fell below or rose above the limits fixed for it. In this way, by increasing or decreasing the loss of action on the part of the pumps, water was pumped out of the well at nearly a uniform rate, while both the speed of the Engines and head against the pumps varied continually.

In order, therefore, to get a fair average of the pressure obtaining in the pumps, it would require a very great number of cards. With the number of cards taken — whilst each individual card is undoubtedly correct — the average pressures represented by them, must be regarded as being approximate only.

The cards were measured with a planimeter, because it is a simpler and more accurate way than by ordinates.

TABLE OF PRESSURES.—FROM PUMP CARDS.

DATE.	TIME.	Head against Pumps See Page 14.	Loan on Pump Pistons. See page 56 of Appendix.	NORTH P'MP.		SO. PUMP.	
				No. of C'rd.		No. of C'rd.	
1874.	H. M.	Feet.	Pounds.		Pounds.		Pounds.
	A. M.						
Dec. 12.	4.10	153.7	----------	--	----------	1	84.1
	4.14	----------	----------	--	----------	2	84.8
	4.23	----------	----------	--	----------	3	85.6
	4.26	----------	----------	--	----------	4	83.9
	4.28	----------	----------	--	----------	5	84.9
	4.30	154.0	----------	--	----------	6	85.8
	4.33	----------	----------	--	----------	7	86.0
	4.35	----------	----------	--	----------	8	85.3
	4.36	----------	----------	--	----------	9	84.2
	5.20	----------	----------	1	86.6	--	--------
	5.22	----------	----------	2	83.5	--	--------
	5.24	----------	----------	3	84.5	--	--------
	5.25	----------	----------	4	84.7	--	--------
	5.27	146.2	----------	5	84.9	--	--------
	5.35	----------	----------	--	----------	10	84.8
	5.39	----------	----------	6	84.7	--	--------
Average, --		149.6	69.82		84.82		84.94
	P. M.						
Dec. 12.	8.21	----------	----------	7	79.8	--	--------
	8.24	----------	----------	8	80.8	--	--------
	8.30	138.9	----------	9	78.1	--	--------
	8.34	----------	----------	10	79.9	--	--------
	8.00	----------	----------	11	71.4	--	--------
	8.59	----------	----------	--	----------	11	87.5
	9.03	141.7	----------	--	----------	12	86.6
	9.05	----------	----------	--	----------	13	87.2
Average, --		140.3	66.31		78.0		87.1
	P. M.						
Dec. 14.	1.55	----------	----------	--	----------	14	83.9
	2.00	136.1	----------	--	----------	15	84.8
	2.03	----------	----------	--	----------	16	85.1
	2.04	----------	----------	--	----------	17	85.1
	3.28	----------	----------	--	----------	18	87.2
	3 30	137.2	----------	--	----------	19	87.9
	3.32	----------	----------	--	----------	20	88.1
	3.35	----------	----------	--	----------	21	86.6
	3.36	----------	----------	--	----------	22	90.1
	4.25	----------	----------	12	75.4	--	--------
	4.28	----------	----------	13	73.5	--	--------
	4.30	136.9	----------	14	74.4	--	--------
	4.40	----------	----------	15	73.7	--	--------
	4.45	----------	----------	16	75.9	--	--------
Average, --		136.43	65.49		74.58		86.53

TABLE OF PRESSURES.—FROM PUMP CARDS.

DATE.	TIME.	Head against Pumps. See Page 14.	Loan on Pump Pistons. See page 56 of Appendix.	NORTH P'MP.		SO. PUMP.	
				No. of C'rd.		No. of C'rd.	
1874.	H. M.	Feet.	Pounds.		Pounds.		Pounds.
	P. M.						
Dec. 14.	5.55	----------	----------	17	73.9	--	--------
	7.40	----------	----------	--	----------	23	80.0
	8.00	140.0	----------	18	74.1	--	--------
	8.00	----------	----------	19	87.8	--	--------
	8.10	----------	----------	20	75.3	--	--------
	8.36	----------	----------	21	73.3	--	--------
	8.46	----------	----------	22	83.0	--	--------
	9.00	144.0	----------	--	----------	24	89.4
	9.28	----------	----------	23	77.4	--	--------
Average...		141.11	65.86		77.83		84.7
	P. M.						
Dec. 14.	9.45	----------	----------	--	----------	25	90.4
	9.48	----------	----------	--	----------	26	87.1
	9.54	----------	----------	24	76.2	--	--------
	9.57	----------	----------	25	76.1	--	--------
	10.00	150.2	----------	26	78.7	--	--------
	10.05	----------	----------	--	----------	27	87.7
	10.30	150.2	----------	--	----------	28	91.0
	10.36	----------	----------	27	80.7	--	--------
	11.01	150.4	----------	28	77.9	--	--------
	11.05	----------	----------	--	----------	29	89.9
Dec. 15.	A. M.						
	0.05	150.9	----------	--	----------	30	89.0
	0.10	----------	----------	--	----------	31	90.8
	0.14	----------	----------	29	78.4	--	--------
	0.17	----------	----------	30	79.0	--	--------
	0.50	----------	----------	--	----------	32	84.8
	0.56	----------	----------	--	----------	33	84.7
	0.59	----------	----------	31	80.3	--	--------
	1.00	149.7	----------	32	80.3	--	--------
	1.01	----------	----------	33	80.3	--	--------
	1.03	----------	----------	34	80.3	--	--------
Average...		150.21	69.72		78.93		88.38

Table 4 Gives a summary of the pressures of all the steam cards taken during the trials.

The indicator springs used for taking the cards, from and after 9:35 P. M., December 11, were believed to be inaccurate, and sent to the American Steam Gauge Company, to be tested. They were found too weak:

indicating too great a pressure by one in sixteen, or 1.0625 times unity.

The cards having all been figured up, and the results tabulated, before the degree or extent of error in the springs was ascertained, corrections were, therefore, made upon the average pressures from all the cards in each period, instead of using a scale specially made for the springs, and thereby correcting each card separately.

The corrections were made by the following formula, which must be used in ascertaining the correct pressures of any single card; the corrections having been made only for the averages.

Let P represent, on the card, the indicated pressure, above the line of perfect vacuum, at any point or ordinate; P^1 the pressure of the atmosphere above the line of perfect vacuum, and P^2 the corrected pressure above the line of perfect vacuum, at any point or ordinate of the card: Then

$P^2 = P^1 + (P - P^1 \times 0.9375)$ = the corrected pressure at any ordinate of the card, at which the indicated pressure is greater than the atmosphere; and

$P^2 = P^1 - (P^1 - P \times 0.9375)$ = the corrected pressure at any ordinate of card, at which the indicated pressure is less than the atmosphere.

By applying these corrections successively to the pressures, at all the ordinates of a card, points will be obtained through which the correct line of pressures passes for such card.

In making up the pressures from the cards, one-tenth the difference between the additive and subtractive pressures at the ordinates, 0.05, 0.15, 0.25, 0.35, 0.45, 0.55, 0.65, 0.75, 0.85 and 0.95 on the card, was not taken as the net average pressure represented. This is the usual method adopted; but, by inspection of these cards, it will be readily seen that this mode of determining the pressure

for each card would give too high an average, on account of the admission and exhaust lines of the card.

The plan adopted was to draw the ordinates in the usual way, and then taking one-tenth the difference between the additive and subtractive pressures, as follows: ¼ at ordinate 0, plus ¼ at ordinate 0.05, plus ½ at ordinate 0.05, plus the pressures at ordinates 0.15, 0.25, 0.35, 0.45, 0.55, 0.65, 0.75, 0.85, plus ½ at ordinate 0.95, plus ¼ at ordinate 0.95, and plus ¼ at ordinate 1.0.

This mode divides the ends of the cards at the rate of twenty instead of ten divisions, and gives results very nearly agreeing with measurements by the planimeter, which latter is the most accurate way of measuring cards when the average pressure only is sought.

Copies of representative cards are hereto appended.

At o.	
1.	
+	
29.	
	14.5
	14.9
	14.7
	16.8
	16.7
	16.6
	16.9
5	16.75
9	14.765
	12.0
	12.0
	12.4
	12.0
	12.0
	12.1
	12 0
	11.3
	11.3
	11.3
	11.2
	12.8
	12.5
	11.4
	12.0
	11.7
	12.1
	11.8
	12.0
	12.2
	10.8
	13.2
	13.5
	13.2
3	12.033
	12.191
	17.7
	17.4
	17.2
	17.1
	17.0
	16.8
	17.1
	16.6
	16.0
	17.0
	16.90
4	16.838

At 0.85. 1.		At 0.95. ½.		At 0.95. ¼.		End or At 1. ¼.		Net Average.
+	−	+	−	+	−	+	−	+
29.	30.	31.	32.	33.	34.	35.	36.	37.
14.5	4.4	6.55	4.0	3.275	2.0	3.225	3.225	23.5
14.9	4.7	6.65	4.0	3.325	2.0	3.25	3.25	22.9
14.7	4.55	6.6	4.0	3.3	2.0	3.238	3.238	23.2
16.8	4.4	7.6	4.45	3.8	2.295	3.675	3.25	26.0
16.7	4.1	7.6	4.25	3.8	2.125	3.625	3.475	26.1
16.6	4.9	7.6	4.45	3.8	2.225	3.65	3.45	24.7
16.9	5.0	7.7	4.6	3.85	2.3	3.725	3.625	25.5
16.75	4.6	7.625	4.438	3.813	2.219	3.669	3.45	25.575
14.765	5.223	7.603	4.616	3.802	2.308	3.672	3.462	23.65
12.0	4.0	5.5	3.45	2.75	1.725	2.6	2.45	19.8
12.0	4.0	5.5	3.4	2.75	1.7	2.7	2.35	19.5
12.4	3.8	5.6	3.4	2.8	1.7	2.75	2.475	20.9
12.0	3.4	5.5	3.35	2.75	1.675	2.7	2.475	21.0
12.0	3.8	5.5	3.25	2.75	1.625	2.7	2.425	20.9
12.1	3.8	5.55	3.25	2.775	1.625	2.675	2.325	21.0
12 0	3.9	5.55	3.4	2.775	1.7	2.75	2.5	20.8
11.3	3.0	5.2	3.05	2.6	1.525	2.5	2.25	20.7
11.3	3.1	5.25	3.0	2.625	1.5	2.475	2.225	20.9
11.3	3.0	5.05	3.0	2.525	1.5	2.45	2.225	20.8
11.2	3.0	5.05	3.0	2.525	1.5	2.475	2.35	20.9
12.8	3.6	5.7	3.25	2.85	1.625	2.75	2.5	21.7
12.5	3.8	5.6	3.5	2.8	1.75	2.7	2.575	21.8
11.4	3.1	5.2	3.2	2.6	1.6	2.45	2.325	20.6
12.0	3.3	5.5	3.1	2.75	1.55	2.725	2.4	21.3
11.7	3.1	5.3	3.0	2.65	1.5	2.525	2.225	22.9
12.1	3.2	5.5	3.35	2.75	1.675	2.725	2.45	21.6
11.8	3.9	5.4	3.25	2.7	1.625	2.625	2.5	20.2
12.0	3.4	5.5	3.25	2.75	1.625	2.6	2.4	21.2
12.2	3.3	5.55	3.3	2.775	1.65	2.725	2.4	21.3
10.8	3.0	4.9	3.0	2.45	1.5	2 35	2.225	19.6
13.2	3.6	6.0	3.1	3.0	1.55	2.975	2.525	22.4
13.5	4.1	6.25	3.65	3.125	1.825	3.0	2.75	22.2
13.2	3.8	6.0	3.45	3.0	1.725	2.85	2.5	22.3
12.033	3.5	5.485	3.241	2.743	1.624	2.657	2.409	21.096
12.191	4.191	5.597	3.494	2.799	1.75	2.719	2.486	19.7
17.7	5.0	8.0	5.0	4.0	2.5	3.875	3.625	26.1
17.4	6.0	7.8	4.75	3.9	2.375	3.775	3.5	24.9
17.2	5.6	7.65	4.5	3.825	2.25	3.65	3.375	25.3
17.1	5.6	7.75	4.8	3.875	2.4	3.75	3.4	25.2
17.0	5.1	7.6	4.5	3.8	2.25	3.725	3.425	26.1
16.8	5.5	7.6	4.6	3.8	2.3	3.7	3.275	25.3
17.1	5.0	7.7	4.65	3.85	2.325	3.75	3.475	25.8
16.6	5.0	8.2	4.5	4.1	2.25	4.025	3.5	25.3
16.0	5.0	7.15	4.0	3.575	2.0	3.4	3.075	25.1
17.0	5.1	7.5	4.6	3.75	2.3	3.675	3.3	25.6
16.90	5.29	7.695	4.59	3.848	2.295	3.733	3.395	25.47
16.838	5.869	7.669	4.758	3.835	2.379	3.702	3.410	23.89

DATE.	TIME.	At 0.85. 1		At 0.95. ½		At 0.95. ¼		At 1. ¼		Net Average.
		+	−	+	−	+	−	+	−	+
1	2	29	30	31	32	33	34	35	36	37
1874. P.M. Dec. 11.	3.2									
	3.36	25.0	5.3	11.25	5.45	5.625	2.725	5.35	5.1	31.7
	3.48	25.8	5.0	11.5	5.0	5.75	2.5	5.5	4.95	32.8
	3.48	25.1	5.0	11.35	5.0	5.675	2.5	5.5	4.625	32.3
	0	24.6	5.3	11.0	5.25	5.5	2.625	5.25	4.75	31.2
	775	25.125	5.15	11.275	5.175	5.638	2.588	5.4	4.856	32.0
A.M. Dec. 12.	12.2									
	12.32	28.8	5.0	12.85	5.75	6.425	2.875	6.125	5.675	35.2
	12.30	28.7	5.0	12.75	5.85	6.375	2.925	6.0	5.175	35.3
	12.46	28.4	5.5	12.8	6.45	6.4	3.225	6.15	5.6	34.9
	12.40	29.3	4.5	12.8	5.9	6.4	2.95	6.0	5.65	34.4
	0	29.3	4.9	13.0	6.4	6.5	3.2	6.15	5.75	35.8
Corrected Pres		28.9	4.98	12.84	6.07	6.42	3.035	6.085	5.57	35.12
	754	28.004	5.58	12.493	6.146	6.246	3.073	5.932	5.45	32.8
A.M. Dec. 12.	10.0									
	10.28	19.7	5.0	8.9	4.0	4.45	2.0	4.225	3.75	28.9
	10.38	19.3	4.9	8.7	3.85	4.35	1.925	4.1	3.8	28.8
	10.50	19.5	4.6	8.75	3.8	4.375	1.9	4.125	3.75	29.0
P.M.	12.19	19.5	4.1	8.7	3.45	4.35	1.725	4.2	3.75	29.7
	12.38	19.7	4.8	8.75	4.0	4.375	2.0	4.2	3.775	29.6
	1.24	19.0	3.7	8.6	3.5	4.3	1.75	4.125	3.65	29.8
	1.24	19.0	3.7	8.5	3.5	4.25	1.75	4.125	3.575	29.8
	2.49	19.1	4.1	8.6	3.4	4.3	1.7	4.125	3.65	29.1
	3.02	19.8	3.5	8.5	2.55	4.25	1.275	4.0	3.375	30.7
	3.08	18.3	3.1	8.3	3.3	4.15	1.65	3.925	3.5	30.7
	3.07	18.5	3.5	8.25	3.5	4.125	1.75	3.975	3.575	29.7
	4.28	18.6	3.1	8.25	3.35	4.125	1.675	3.925	3.525	30.0
	4.36	20.9	4.0	9.35	4.75	4.675	2.375	4.5	4.25	31.0
	5.03	18.9	3.8	8.5	4.0	4.25	2.0	4.025	3.75	29.7
	5.16	19.8	3.7	8.8	3.4	4.4	1.7	4.175	3.5	30.8
	5.15	19.0	3.5	8.5	3.15	4.25	1.575	4.1	3.4	30.2
	5.26	19.4	3.5	8.6	3.5	4.3	1.75	4.0	3.5	30.6
	5.21	18.8	3.6	8.5	3.55	4.25	1.775	4.0	3.5	29.7
	5.36	19.2	4.0	8.65	4.1	4.325	2.05	4.0	3.525	29.9
	5.35	20.0	3.9	9.0	3.45	4.5	1.725	4.25	3.525	30.4
	5.49	22.2	4.0	9.9	5.0	4.95	2.5	4.7	4.375	32.3
	5.49	22.2	4.6	9.9	4.15	4.95	2.075	4.725	4 0	31.2
	5.44	22.0	4.0	9.8	4.25	4.9	2.125	4.675	4.0	31.3
	7.58	22.2	4.4	9.95	4.35	4.975	2.175	4.75	4.25	31.7
	5	25.0	4.0	11.15	4.45	5.575	2.225	5.25	4.425	34.7
Corrected Pres	476	19.984	3.964	8.936	3.772	4.468	1.886	4.248	3.747	30.372
	169	19.645	4.626	8.833	3.991	4.416	1.996	4.210	3.740	28.4
P.M. Dec. 14.	2.05									
	4.07	23.2	4.0	10.75	4.5	5.375	2.25	5.25	4.75	32.1
	4.15	24.5	5.0	11.0	5.0	5.5	2.5	5.25	4.875	32.2
	4.30	24.8	4.4	11.05	4.9	5.525	2.45	5.325	4.8	32.8
	5.05	24.6	5.4	11.0	5.4	5.5	2.7	5.25	4.75	32.1
	5.20	24.7	5.3	11.0	5.0	5.5	2.5	5.25	4.675	32.5
	5.30	24.0	5.6	10.8	5.0	5.4	2.5	5.075	4.625	31.7
	5.45	24.8	5.5	11.05	5.25	5.525	2.625	5.25	4.7	32.3
	6.50	25.0	4.7	11.2	4.5	5.6	2.25	5.425	4.45	32.0
	6.25	24.5	4.1	11.15	3.85	5.575	1.925	5.0	4.25	32.5
	0	24.8	4.8	11.15	4.15	5.575	2.075	5.25	4.85	32.6
Corrected Pres	36	24.49	4.88	11.015	4.755	5.508	2.378	5.233	4.673	32.28
	997	23.869	5.485	10.752	4.913	5.391	2.457	5.134	4.609	30.2

T 0.85.

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89 4·1
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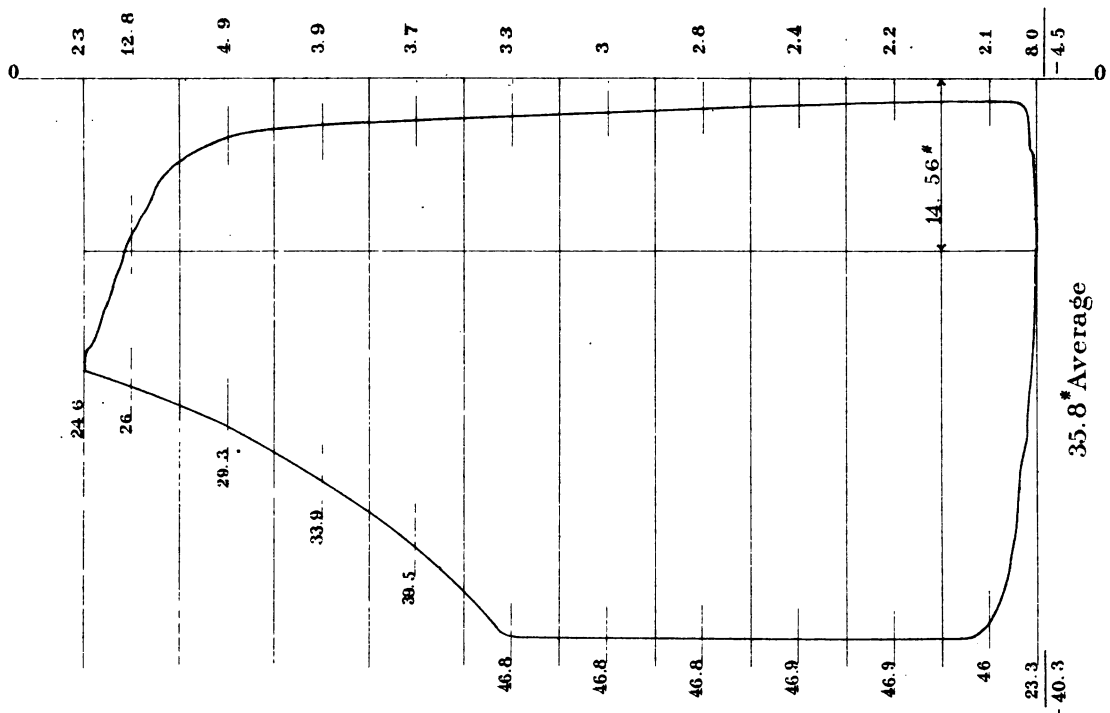
	T 0.85. 1.		At 0.95. ½.		At 0.95. ¼.		End or At 1. ¼.		Net Average.
		—	+	—	+	—	+	—	+
		30	31	32	33	34	35	36	37.
		4.3	5.05	3.5	2.525	1.75	2.5	2.4	16.7
		2.4	4.5	2.55	2.25	1.275	2.125	2.0	18.4
P.	5	3.35	4.775	3.025	2.388	1.513	2.313	2.2	17.55
Dec.		4.0	5.95	3.5	2.975	1.75	2.925	2.5	22.0
		4.1	5.95	3.5	2.975	1.75	2.85	2.525	21.7
		4.4	6.45	4.0	3.225	2.0	3.05	3.0	22.5
		4.0	6.1	3.75	3.05	1.875	2.95	2.775	22.4
		4.5	6.3	3.9	3.15	1.95	3.0	2.7	22.4
		4.1	6.25	3.7	3.125	1.85	3.0	2.7	22.9
		3.9	6.45	3.9	3.225	1.95	3.05	2.925	23.7
		4.0	6.4	3.6	3.2	1.8	3.025	2.6	23.6
		4.6	6.55	4.35	3.275	2.175	3.175	3.025	23.6
Corr.	89	4.178	6.266	3.8	3.133	1.9	3.003	2.75	22.756
	37	4.827	6.33	4.018	3.165	2.009	3.043	2.806	21.4
Dec.		4.4	4.65	3.0	2.325	1.5	2.25	2.075	15.6
		3.9	4.35	2.9	2.175	1.45	2.05	2.05	15.1
		4.7	4.8	3.25	2.4	1.625	2.275	2.2	15.3
		6.4	5.5	3.95	2.75	1.975	2.625	2.625	15.5
		6.0	5.4	3.85	2.7	1.925	2.6	2.425	15.6
P.		6.1	5.5	3.9	2.75	1.9	2.65	2.5	15.5
		3.1	4.25	2.55	2.125	1.275	2.05	1.975	16.2
		2.9	4.4	2.7	2.2	1.35	2.2	2.0	17.2
		3.0	4.5	2.65	2.25	1.325	2.15	1.975	17.4
		1.6	3.75	1.95	1.875	0.975	1.75	1.6	17.9
		3.0	5.55	3.25	2.775	1.625	2.65	2.4	22.1
		3.0	5.0	3.05	2.5	1.525	2.4	2.4	19.9
		3.0	5.0	3.0	2.5	1.5	2.425	2.3	20.0
		3.1	5.7	3.2	2.85	1.6	2.7	2.425	22.3
		3.0	5.5	3.05	2.75	1.525	2.575	2.325	21.6
		2.9	5.5	3.0	2.75	1.5	2.6	2.275	22.0
		3.1	5.7	3.4	2.85	1.7	2.725	2.525	22.0
Corr.	29	3.718	5.003	3.097	2.501	1.549	2.39	2.24	18.306
P.	56	4.396	5.146	3.359	2.572	1.679	2.468	2.328	17.1
Dec.		3.4	5.8	3.55	2.9	1.775	2.775	2.5	22.8
		3.4	5.55	3.65	2.775	1.825	2.725	2.775	22.1
		3.3	5.95	3.6	2.975	1.8	2.825	2.7	22.8
		3.6	5.95	3.55	2.975	1.775	2.825	2.675	22.9
		3.3	6.05	3.75	3.025	1.875	2.875	2.75	22.8
		3.1	5.95	3.5	2.975	1.75	2.825	2.675	23.2
		3.6	6.0	4.0	3.0	2.0	2.95	2.775	22.8
		3.3	6.0	3.7	3.0	1.85	2.875	2.75	22.9
		3.3	6.0	3.55	3.0	1.775	2.875	2.75	23.2
		3.2	5.9	3.65	2.95	1.825	2.8	2.625	23.3
		3.1	5.9	3.5	2.95	1.75	2.8	2.65	23.4
		3.0	6.0	3.55	3.0	1.775	2.825	2.625	23.4
		3.5	6.0	3.65	3.0	1.825	2.875	2.775	23.1
		3.1	5.85	3.65	2.925	1.825	2.75	2.675	22.9
		2.8	5.95	3.55	2.975	1.775	2.8	2.675	23.4
		3.1	6.0	3.5	3.0	1.75	2.85	2.625	23.3
		3.1	6.0	3.5	3.0	1.75	2.825	2.65	23.1
Corr.	65	3.247	5.932	3.612	2.966	1.806	2.828	2.685	23.023
	52	3.954	6.016	3.841	3.008	1.921	2.879	2.745	21.6

DAT	At 0.85. 1		At 0.95. ½		At 0.95. ¼		At 1. ¼		Net Average.
	+	−	+	−	+	−	+	−	+
1	29	30	31	32	33	34	35	36	37
1874. Dec.	21.0	5.8	9.5	5.1	4.75	2.55	4.55	4.3	28.3
	21.2	5.6	9.4	5.1	4.7	2.55	4.55	4.45	28.3
P. Dec.	21.1	5.7	9.45	5.1	4.725	2.55	4.55	4.375	28.3
	26.2	5.3	11.5	5.7	5.75	2.85	5.5	5.25	33.4
	26.1	5.1	11.55	5.5	5.775	2.75	5.5	4.8	33.2
	26.0	5.3	11.5	5.9	5.75	2.95	5.5	5.2	32.8
	27.0	5.0	11.8	5.5	5.9	2.75	5.55	5.25	33.6
	27.2	5.4	12.0	5.55	6.0	2.775	5.675	5.3	33.9
	27.6	5.2	12.5	6.0	6.025	3.0	5.75	5.6	34.1
Co.r.c	26.683	5.217	11.733	5.692	5.867	2.846	5.579	5.233	33.5
	25.925	5.801	11.455	5.751	5.728	2.896	5.458	5.134	31.4
A. Dec.	25.5	7.4	11.5	5.95	5.75	2.975	5.5	4.975	31.1
	25.6	7.2	11.55	5.7	5.775	2.85	5.5	4.725	31.7
	23.9	5.1	10.5	4.2	5.25	2.1	5.0	4.5	31.7
	23.5	5.4	10.25	5.0	5.125	2.5	4.85	4.5	30.4
	24.6	5.5	10.4	5.45	5.2	2.725	4.95	4.55	31.6
	24.9	6.9	11.0	6.0	5.5	3.0	5.25	4.975	31.3
	25.3	7.1	11.4	5.0	5.7	2.5	5.375	4.2	31.5
	22.7	4.5	10.0	3.05	5.0	1.525	4.775	3.0	31.6
	24.0	7.7	10.95	6.05	5.475	3.025	5.25	5.0	30.4
	21.5	4.8	9.75	4.95	4.875	2.475	4.625	4.25	31.1
M	22.0	4.5	9.9	5.45	4.95	2.725	4.725	4.425	31.8
P. M	20.8	3.8	9.45	4.05	4.725	2.025	4.475	4.0	31.6
	21.0	4.0	9.5	5.3	4.75	2.65	4.5	4.15	30.2
	21.1	4.0	9.5	4.5	4.75	2.25	4.55	4.225	32.0
	22.0	4.0	9.8	4.75	4.9	2.375	4.7	4.325	32.4
	22.2	3.3	9.9	4.7	4.95	2.35	4.75	4.475	32.3
	23.9	4.1	10.6	5.25	5.3	2.625	5.0	4.725	33.6
	23.2	4.1	10.3	5.45	5.15	2.725	4.925	4.525	32.8
	23.9	4.0	10.15	4.95	5.075	2.475	4.825	4.3	32.7
	25.5	4.0	11.4	4.45	5.7	2.225	5.35	4.25	34.8
	26.0	4.3	11.6	4.9	5.8	2.45	5.5	4.85	34.8
	25.8	4.0	11.46	4.45	5.725	2.225	5.5	4.475	35.4
Correct	23.545	4.987	10.493	4.98	5.247	2.49	4.994	4.427	32.127
	22.983	5.585	10.292	5.124	5.197	2.562	4.91	4.378	30.1
P. M. Dec. 1	28.5	4.8	12.65	5.75	6.325	2.875	6.0	5.025	36.1
	27.1	4.0	12.1	5.15	6.05	2.575	5.675	4.7	35.9
	28.0	4.2	12.5	5.4	6.25	2.7	5.925	5.275	36.4
	28.0	4.4	12.5	5.1	6.25	2.55	5.925	4.875	36.5
	28.0	4.5	12.45	5.45	6.225	2.725	5.8	5.225	36.6
	28.0	4.7	12.5	5.75	6.25	2.875	5.9	5.05	36.0
	28.0	4.2	12.5	5.35	6.25	2.675	5.925	4.75	36.3
	28.0	4.3	12.5	5.2	6.25	2.6	6.0	5.25	36.6
	27.8	4.0	12.45	5.45	6.225	2.725	5.85	5.425	36.0
	28.0	4.3	12.45	5.05	6.225	2.525	5.9	5.05	36.3
	27.9	4.0	12.4	5.2	6.2	2.6	5.975	4.75	36.9
	28.4	4.1	12.6	5.45	6.3	2.725	6.1	4.6	37.1
	28.0	4.3	12.5	5.25	6.25	2.625	5.875	5.3	36.6
	28.0	4.2	12.45	5.0	6.225	2.5	6.05	4.95	36.3
	28.9	4.2	12.75	5.5	6.375	2.75	6.0	4.925	36.8
	28.8	4.5	12.7	5.8	6.35	2.9	6.0	5.35	36.5
	28.1	4.0	12.55	5.45	6.275	2.725	5.975	5.225	37.0
Correct	28.088	4.276	12.503	5.371	6.251	2.685	5.934	5.043	36.465
	27.243	4.919	12.177	5.491	6.088	2.745	5.791	4.955	34.2

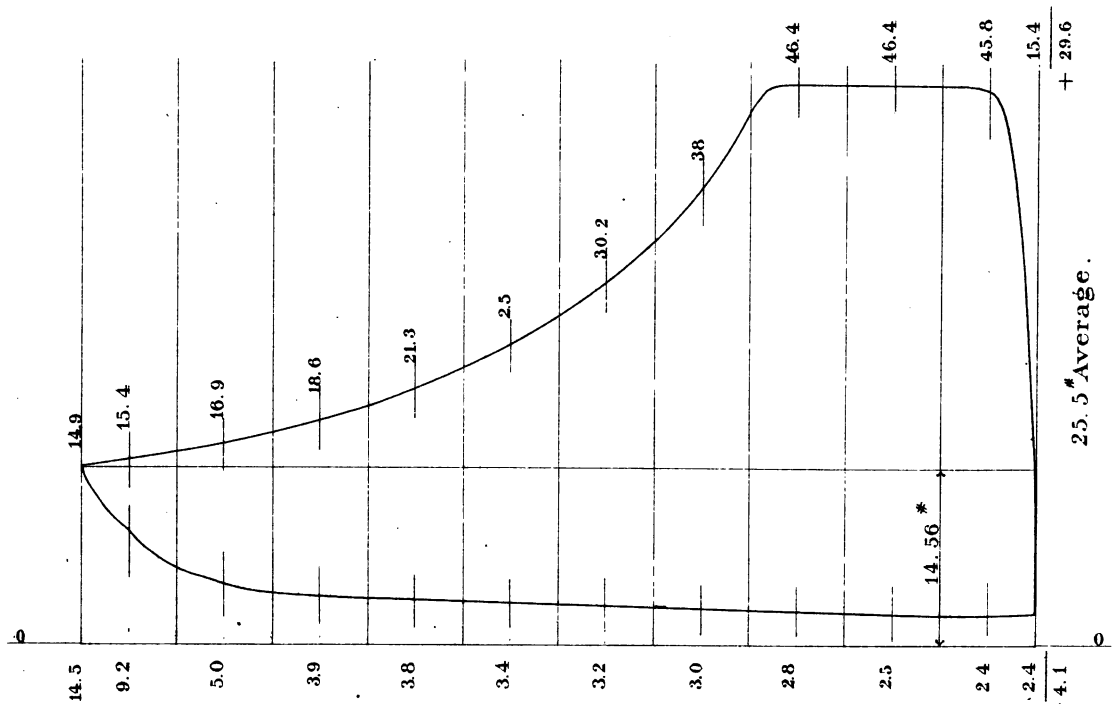
DIAGRAMS.



SOUTH ENGINES.

DECEMBER 12th, 1874, 12:45 A. M.

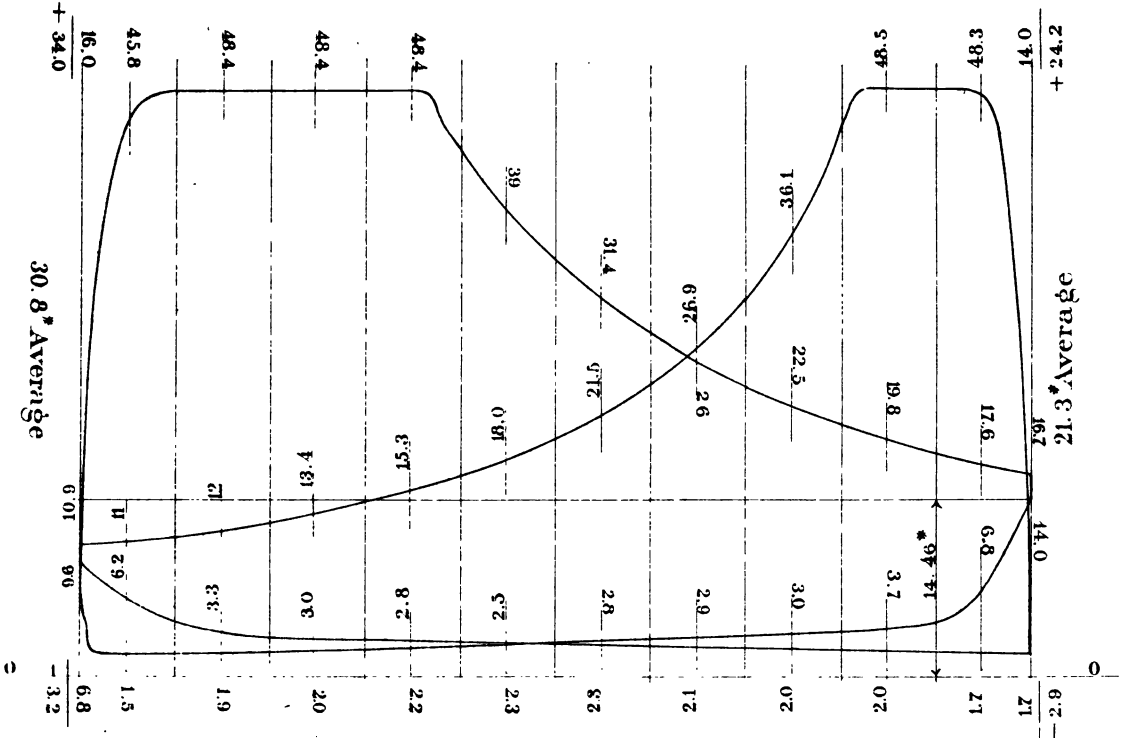
DIAGRAM No. 11, from Lower end of North Steam Cylinder. Diameter, 70 inches; stroke, 10.014 feet; 11.1 revolutions per minute; 222.81 feet piston speed per minute; 29 lbs. steam in boiler; 26.5 inches vacuum; scale, 16 lbs. per inch.



SOUTH ENGINES.

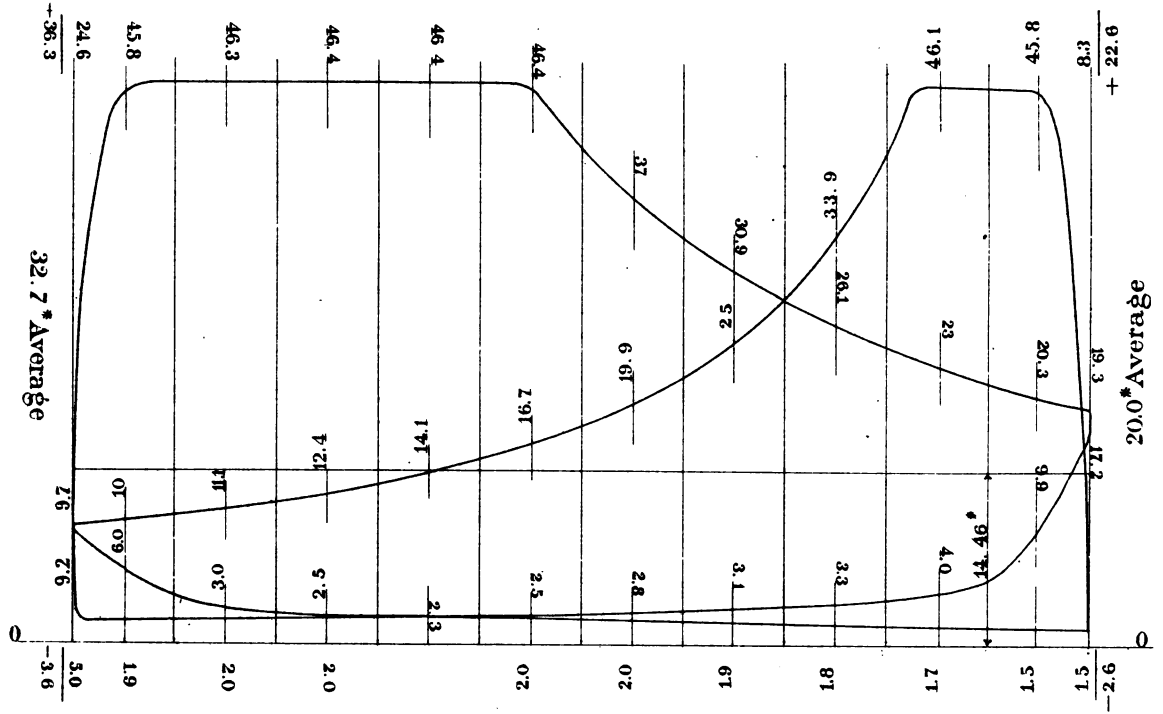
DECEMBER 12th, 1874, 1:00 A. M.

DIAGRAM No. 15, from Upper end of North Steam Cylinder. Diameter, 70 inches; stroke, 10.014 feet; 10.7 revolutions per minute; 214.3 feet piston speed per minute; 82½ lbs. steam in boiler; 26.5 inches vacuum; scale, 16 lbs. per inch.



DECEMBER 12th, 1874, 5:03 P. M.

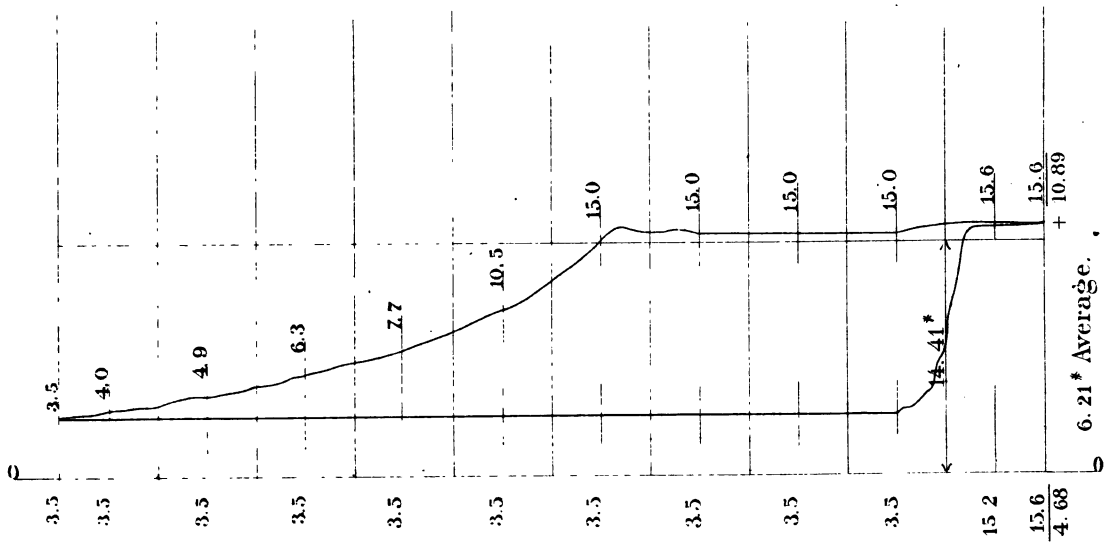
DIAGRAM No. 89, from Upper and Lower ends of North Steam Cylinder. Diameter, 70 inches; stroke, 10.014 feet; 11 revolutions per minute; 220.81 feet piston speed per minute; 30 lbs. steam in boiler; 27 inches vacuum; scale, 16 lbs. per inch.



SOUTH ENGINES.

DECEMBER 12th, 1874, 4:15 P. M.

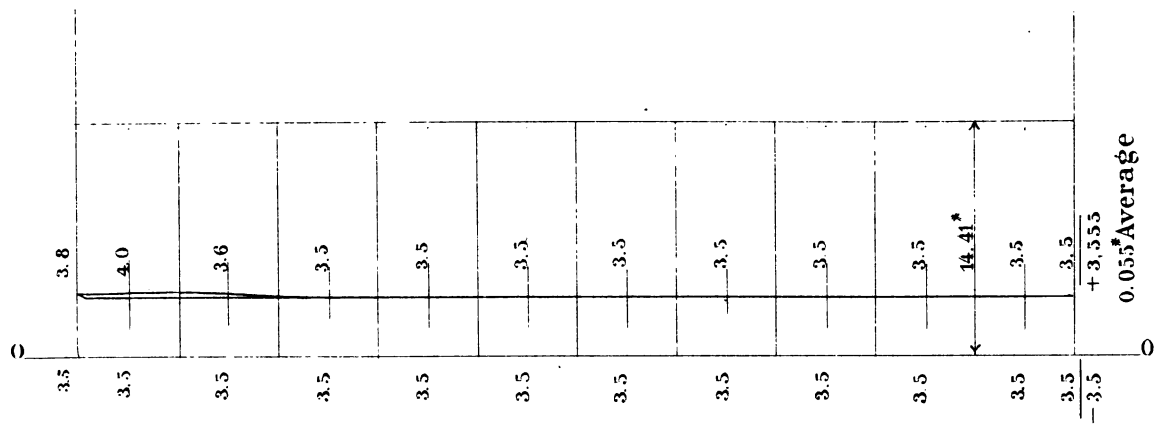
DIAGRAM No. 48, from Upper and Lower ends of South Steam Cylinder. Diameter, 70 inches; stroke, 10.019 feet; 10.9 revolutions per minute; 218.4 feet piston speed per minute; 29 lbs. steam in boiler; 26.5 inches vacuum; scale. 16 lbs. per inch.



SOUTH ENGINES.

DECEMBER 12th, 1874, 9:22 P. M.

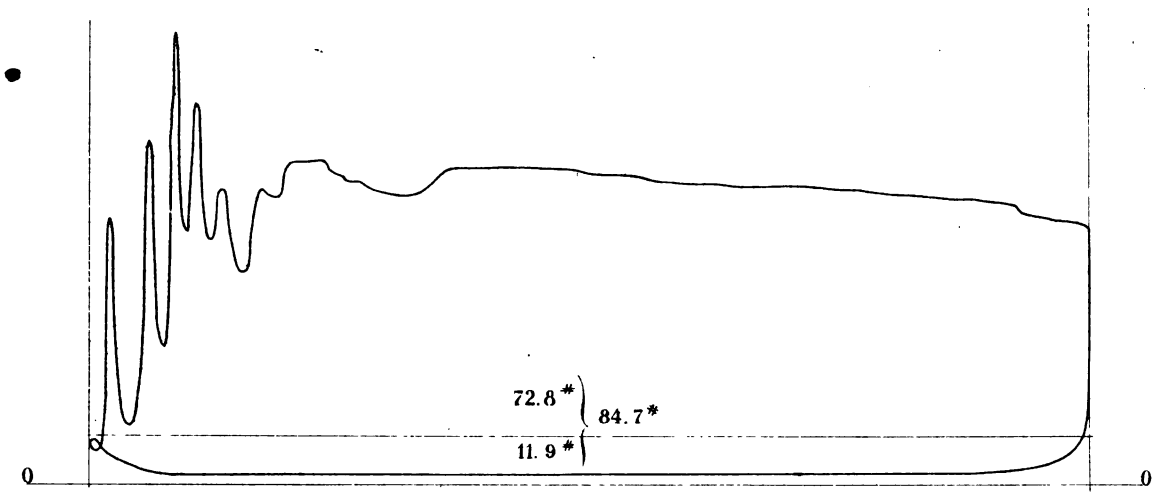
DIAGRAM No. 2, from Upper end of South Air Pump Cylinder. Diameter, 45 inches; stroke, 4.51 feet; 10.9 revolutions per minute; 98.82 feet piston speed per minute; 30 lbs. steam in boiler; 26.5 inches vacuum; 120° Far. hot well water; scale, 12 lbs. per inch.



SOUTH ENGINES.

DECEMBER 12th, 1874, 9:32 P. M.

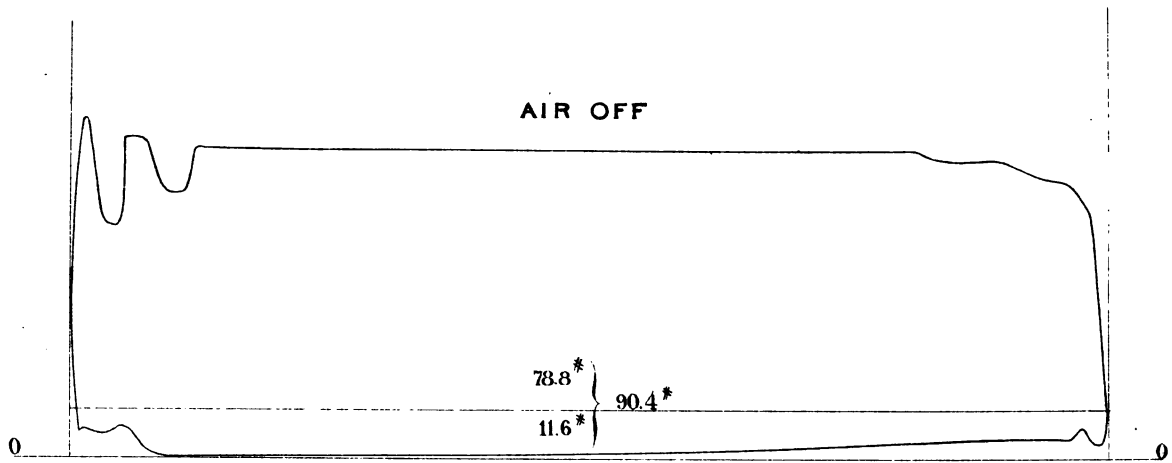
DIAGRAM No. 6, from Lower end of South Air Pump Cylinder. Diameter, 45 inches; stroke, 4.51 feet; 10.9 revolutions per minute; 98.32 feet piston speed per minute; 30 lbs. steam in boiler; 26.5 inches vacuum; 120° Far. hot well water; scale, 12 lbs. per inch.



SOUTH ENGINES.

DECEMBER 12th, 1874, 5:25 A. M.

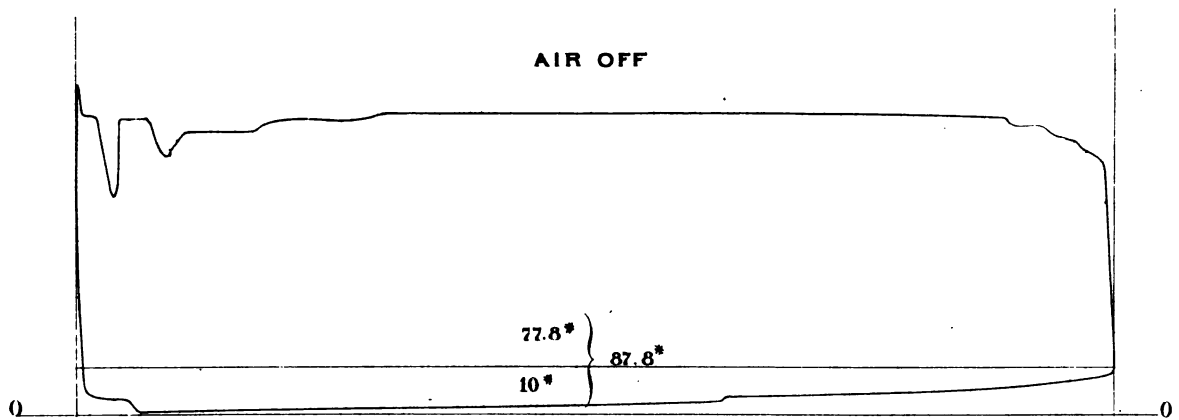
DIAGRAM No. 4, from Lower end of North Pump Cylinder. Diameter, $\left\{\begin{matrix}57.168\\57.048\end{matrix}\right\}$ inches; stroke, 10.014 feet; 10.5 revolutions per minute; 210.29 feet piston speed per minute; scale, 60 lbs. per inch; Head against pump, 146.2 feet.



SOUTH ENGINES.

DECEMBER 12th, 1874, 4:28 A. M.

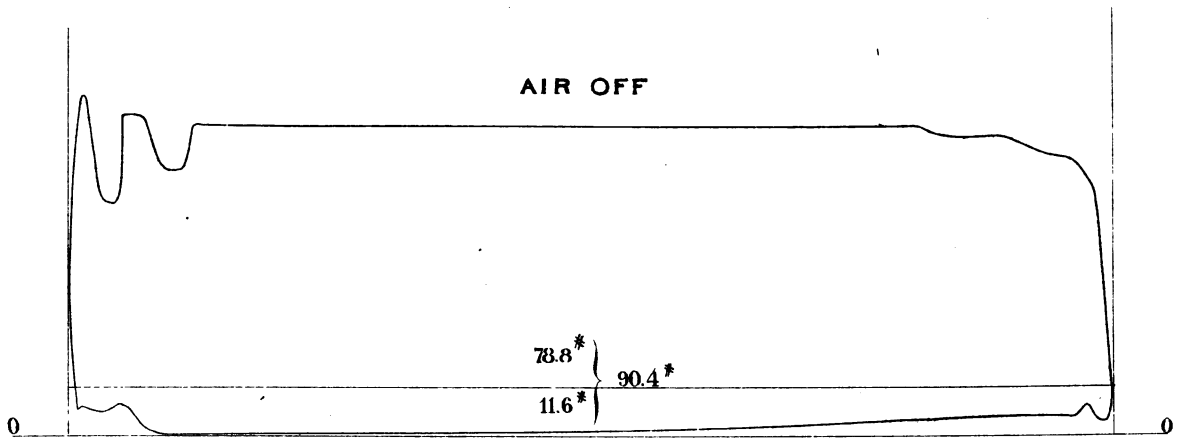
DIAGRAM No. 5, from Lower end of South Pump Cylinder. Diameter, $\left\{\begin{matrix}57.216\\57.144\end{matrix}\right\}$ inches; stroke, 10.019 feet; 10.7 revolutions per minute; 214.41 feet piston speed per minute; scale, 60 lbs. per inch; Head against pump, 154 feet.



SOUTH ENGINES.

DECEMBER 14th, 1874, 8:00 P. M.

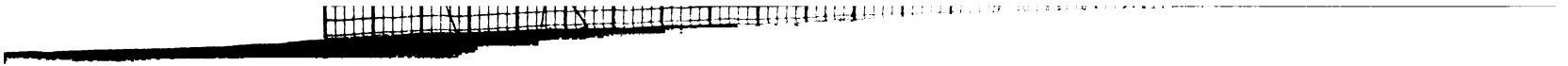
DIAGRAM No. 19, from Lower end of North Pump Cylinder. Diameter, $\left\{\begin{matrix}57.168\\57.048\end{matrix}\right\}$ inches; stroke, 10.019 feet; 11.1 revolutions per minute; 222.42 feet piston speed per minute; scale, 60 lbs. per inch; Head against pump, 140 feet.

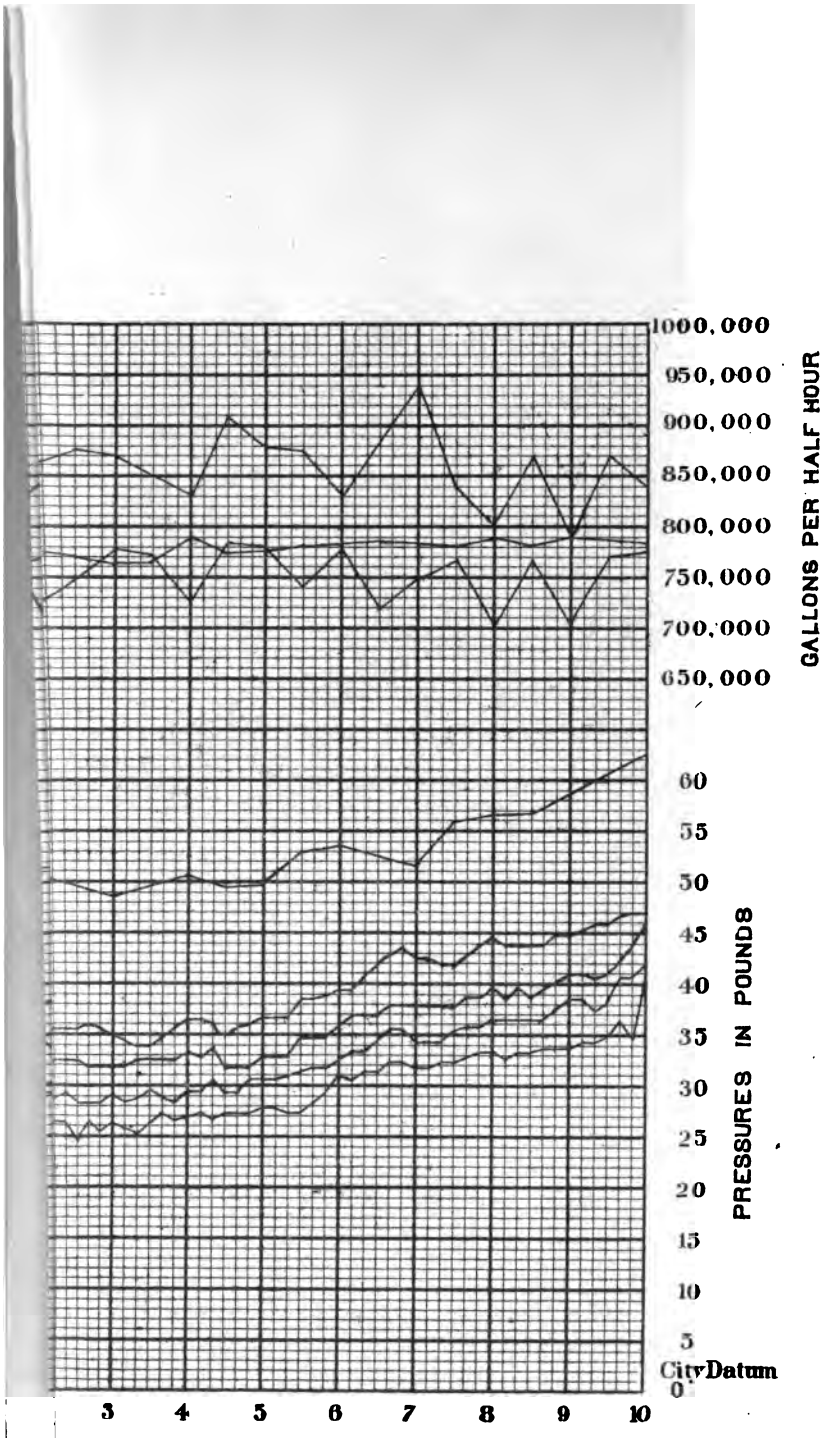


SOUTH ENGINES.

DECEMBER 14th, 1874, 9:25 P. M.

DIAGRAM No. 84, from Lower end of South Pump Cylinder. Diameter, $\left\{\begin{matrix}57.216\\57.144\end{matrix}\right\}$ inches; stroke, 10.019 feet; 10.1 revolutions per minute; 202.38 feet piston speed per minute; scale, 60 lbs. per inch; Head against pump, 143.9 feet.

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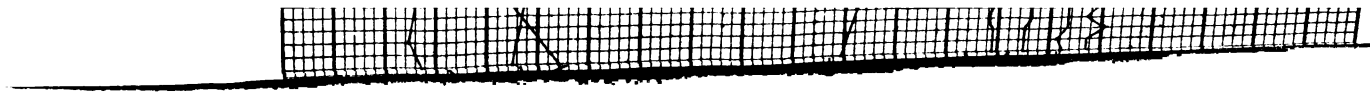

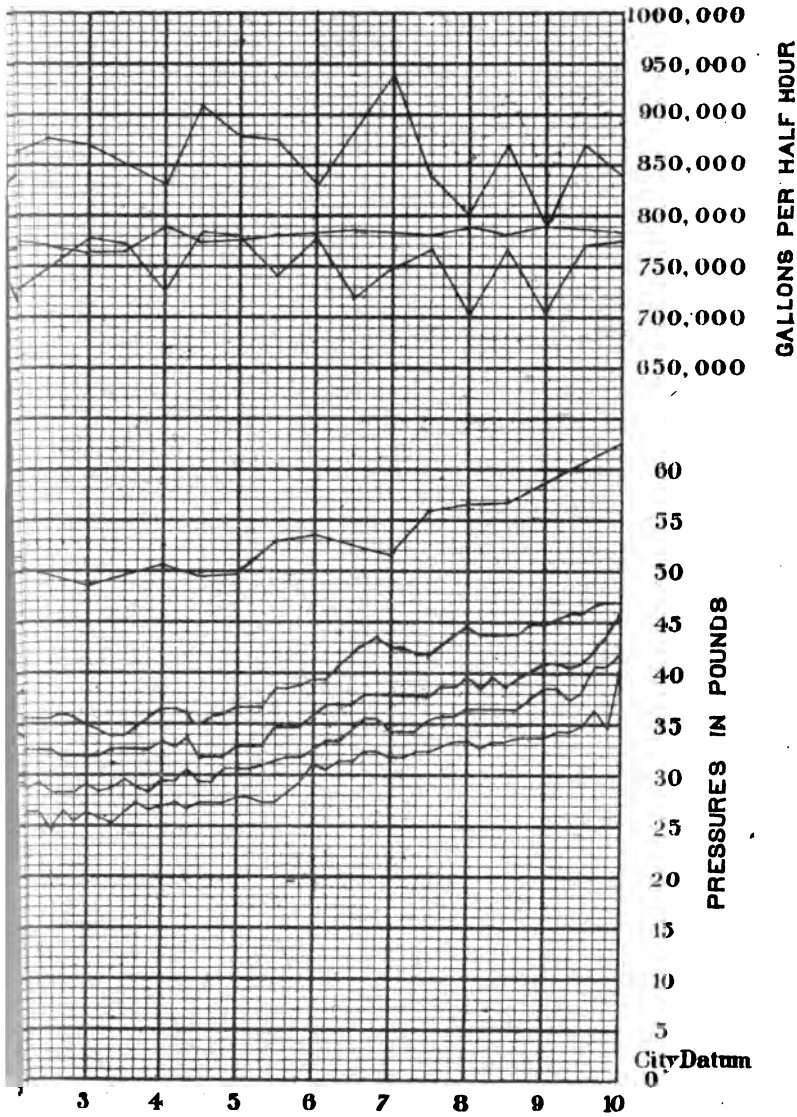
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12TH

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